University of Strathclyde

Department of Management Science

Model of Learning Ability

Thesis submitted for the degree of Doctor of Philosophy

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Acknowledgements

In 1997 I was an MBA student waiting for the first class in decision making. Actually, I was not in a very good mood – I really did not need another semester of optimization, mathematical programming, or anything of the sort. When Zoltán Baracskai started the class by offering a flower to a girl in the first row, to play the usual game, loves-me-loves-me-not, I felt even worse… Then I heard: "Yes, we cheat, but we cheat in order to get to the truth." I have raised my head: something important is going on! – and I became an apprentice of Zoltán Baracskai for the next six years.

The research that is presented in this dissertation is the product of research conducted in the last few years of my apprenticeship in Baracskai's workshop. More precisely, the research was conducted there but I moved to Glasgow, where I have got a lecturer position at Strathclyde University, without taking it to viva – so it had to be rewritten to meet the expectations of a PhD at my new institution.

If I wanted to list all the people who helped me in one way or another with this research and the dissertation writing, it would take a separate volume. All the people who were teaching me, and who I was teaching – I have learned a lot from them. All those whose works I was reading, and those, who read my writings – there were many useful comments. People that welcomed my ideas, and others, who rejected them – I benefited a lot from their critiques. Still, there are some people that I have to mention by name, although it is only a fraction of the full list. My mentor, Zoltán Baracskai, is largely responsible for me becoming a scientist and being happy in this role. I will never be able to repay this to him, fortunately, as he use to say, I do not have to. I have to do the same thing for my future apprentices. My supervisors Fran Ackermann and Terry Williams have done much more than a supervisor usually has to, as they introduced me into this very different academic culture and helped me to transform my results into an appropriate presentation. Rowena Murray, along with my supervisors, helped me with proper use of English, so that I could write what I intended to say; especially to avoid being assertive when I did not want to. I am deeply in their debt. Jaszmina Szendrey, Katalin Molnár, László Kovács not only

helped me with the figures but they have actually drawn most of them, based on my explanations. They receive my thanks for making my dissertation neat and more expressive. Last but not least, I have to mention the enormous patience of my family, my parents, Erzsébet and Viktor Dörfler, and my brother, Zsolt Dörfler. I will probably never have a chance to recompense them fully. My girlfriend, Jaszmina Szendrey was my muse and my helper in every sense. I could not do it without her. Thanks to all these people and to many-many others, that I did not list here by their names.

Abstract

The problem domain of the investigation presented in this dissertation is knowledge increase. In particular the research is concerned with the process of knowledge increase. The research problem formulated is formulated a posteriori: *"Which factors determine the increase of personal knowledge that occurs by absorbing a particular new knowledge of an individual, who is a member of an organization, and how these factors work?"*

To explore and shed light on this problem a number of disciplinary boundaries were engaged and some models, tools, descriptions, etc. were borrowed from a number of related disciplines. These areas are briefly presented in the dissertation, restricting presentation to the relevant issues.

There are three models developed for this thesis and they are subsequently integrated into a fourth model. First the 'Model of Learning Willingness' (MLW) is developed to consider personal and organizational value systems. For this model, new concepts have been created, to indicate the position of new knowledge in both personal and organizational value systems. Stable and the unstable states of the model are identified as well as how it is possible to pass from one state to another as result of an interaction between the two value systems by means of influencing each other.

Applying a 'systems theory approach' on the cognitive psychology conception of knowledge, the impact of the characteristics of existing knowledge on the absorption of new knowledge is described. The developed model is called the 'Model of Learning Capability' (MLC). – This is the second model.

It is also necessary to pay attention to the ability to acquire new knowledge; this is described by the 'Model of Attention' (MA) – the third model. This model is based on two main factors, namely cognitive and social conditions.

These three models are thus integrated into fourth one, which is called the 'Model of Learning Ability' (MLA). For exploration/validation the model is tested with the

Doctus Knowledge-Based Expert System, which was also the means of comparing the evolved hypotheses with the input from reality, namely observations and thought experiments.

The first insight from the model is a better understanding of the process of 'knowledge increase'. The model can also be used to support choosing the right person to learn a particular piece of new knowledge, to identify the reason for someone not performing well with regards to learning and/or identifying a possible way of improving the process. Using the logic of the model experts can also be evaluated in the process of knowledge acquisition when building an expert system.

Considering the achieved results some new problems emerge: It is not known what motivates the personal value system during the knowledge absorption; it is not known if the model can be extended to other forms of knowledge increase besides learning; it is not known how the social factors apart from love (i.e. power and money) affect the attention. Some new research ideas also evolved from this investigation, e.g. an attempt to model the knowledge using dimensions of understanding.

1. Introduction

> *"Reasonable people adapt themselves to the world. Unreasonable people attempt to adapt the world to themselves. All progress, therefore, depends on unreasonable people."*
>
> *George Bernard Shaw*

This dissertation is a story of knowledge increase about knowledge increase, of learning about learning. It could be said more precisely, as shall be shown throughout the dissertation, that the problem domain is 'knowledge increase'. The reason for choosing it is a rather subjective one, or more precisely two: at the time of the decision I had already done substantial reading and research about knowledge, and I was immensely interested in knowledge and learning. More detailed explanation of why exactly the process of knowledge increase is chosen will be given at the point of exact problem formulation in Chapter 5.

Initially there were several component problems identified in this problem domain and, as is often the case, during the process of problem solving some of these disappeared, some were resolved, some were not solved and abandoned, and some were further divided into further component problems. Finally, just before the result was obtained, the problem could be formulated. There was a long way from the initial component problems to the precise description of the problem, for which a model is offered here; along the way frequently decisions had to be taken as to whether or not to consider or include something. This can be envisaged as starting from a problem domain which has many dimensions and fuzzy boundaries, and then chopping off smaller or bigger parts of it (i.e. what is excluded from the further investigation at a certain point), sometimes whole dimensions, until a more manageable amount remains. The proper account for this process can only be given in a negative terms, i.e. what is not included and why. According to Bertalanffy ([1981](#), p. 52), this is always the case if we are exploring something new. For this reason, the first four chapters mainly focus on the negative – what is not included, and the reader is requested to be patient until the problem is finally formulated in a positive form in Chapter 5. However, it is clear that few people would read more than two hundred pages to find out

if they are interested in the topic at all, so a preliminary (if not entirely precise) problem formulation is given here: *it is not known which factors determine whether a person will learn a particular piece new knowledge, and how these factors work.*

This problem is not covered in the literature, as will be shown in Chapter 4 (and to lesser extent in Chapter 3); knowledge increase is usually discussed in terms of teaching techniques. The result presented here is a model, the Model of Learning Ability. It consists of three component models, i.e. there are three major factors considered to determine the learning ability of the person, i.e. whether she/he will be able to learn a particular new knowledge. The three component models are the Model of Learning Willingness, the Model of Learning Capability, and the Model of Attention. These three factors branch further into sub-factors.

As in case of all scientific research, the well-structured report about the results has nothing to do with the ill-structured process of getting to them regardless of the effort to maintain methodological rigour. Any research report accounts for a knowledge increase about the investigated problem. The special feature of this investigation is that the problem itself is 'knowledge increase'. This explains that in the dissertation the process of research is interwoven with the topic itself.

If there is a single dominant line of investigation, it can be presented as a linear logical argument, which includes lateral branches (e.g. inputs from other disciplines, pieces from literature that do not fall into the mainstream of thinking) discussed at the place of their appearance. However, this dissertation comprises the development of a model consisting of three sub-models, which have to be built separately. Consequently there are three major branches of investigation; the backgrounds of these branches sometimes overlap. (See Figure 1) Therefore the previously mentioned single-line-argument approach cannot be used in this dissertation; however, it makes sense to lead the reader in a spiral line of logical argument winding closer and closer to the target. (See Figure 2)
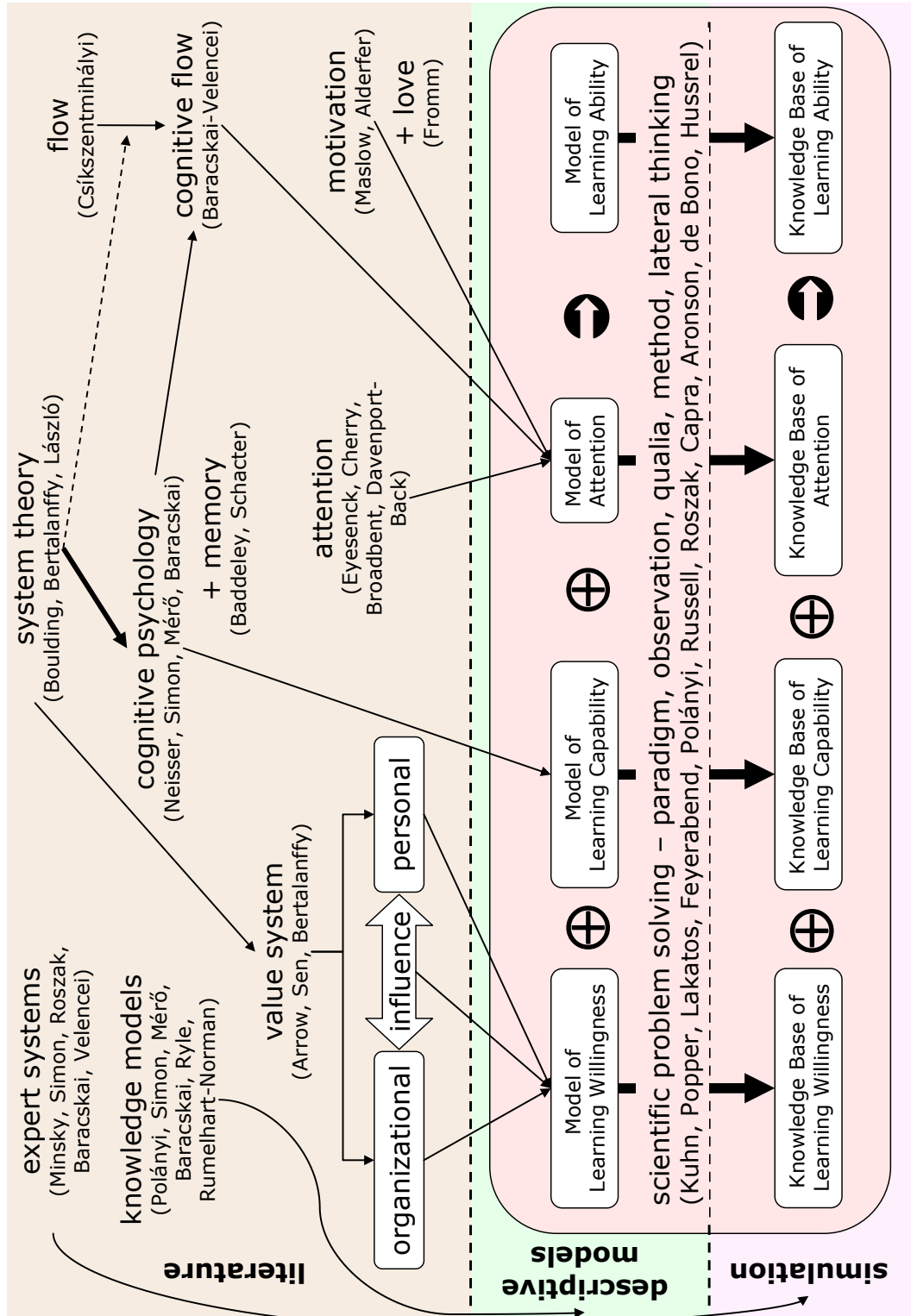
Figure 1: Family tree of the dissertation.[1]

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[1] *This figure is repeated in the appendices, where it can be folded out to keep track of the concepts during the reading; henceforth this picture will be referred to as Appendix 1.*
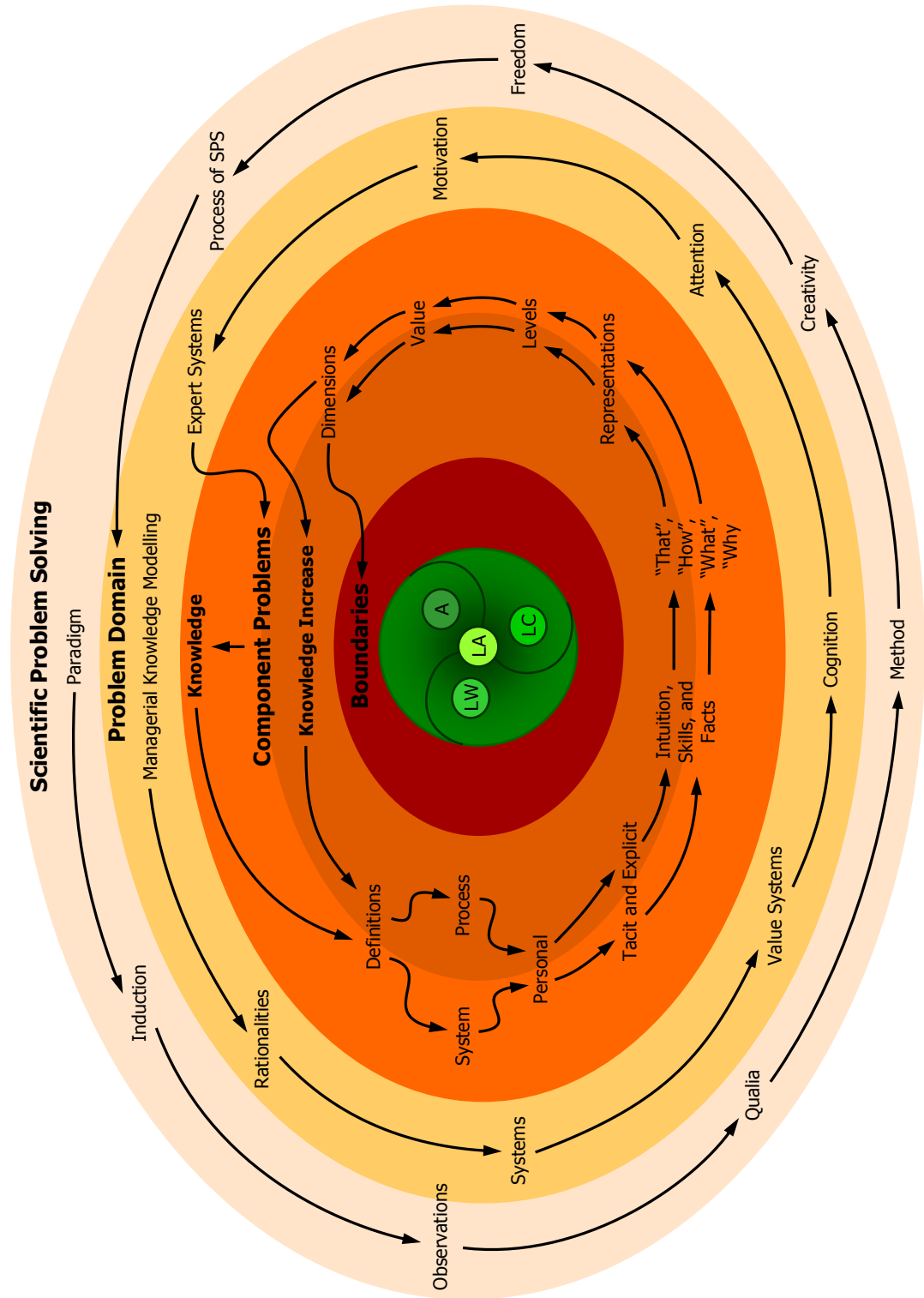
Figure 2: The spiral of discussion: top-view.[1]

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[1] *The following abbreviations are used in this figure: LW – Learning Willingness, LC – Learning Capability, A – Attention, LA – Learning Ability. Similarly to the previous figure this one can also be*

The line of argument is even more comprehensible, if we imagine drilling down, starting from the widest area on the top of the spiral and narrowing it gradually as we drill deeper and deeper. If we adopt this idea, the picture on Figure 2 (Appendix 2) can be regarded as a top-view of the 'hole', while Figure 3 represents the side-view. Figure 2 is more detailed; it actually contains all the section-titles of the dissertation. Figure 3 is smaller, and comes in handy for a large-scale overview; the different cycles of the spiral appear on this picture as layers of the drilling. Inside the 'hole' it is shown what is discussed at each layer and the corresponding chapter titles are indicated beside the picture.
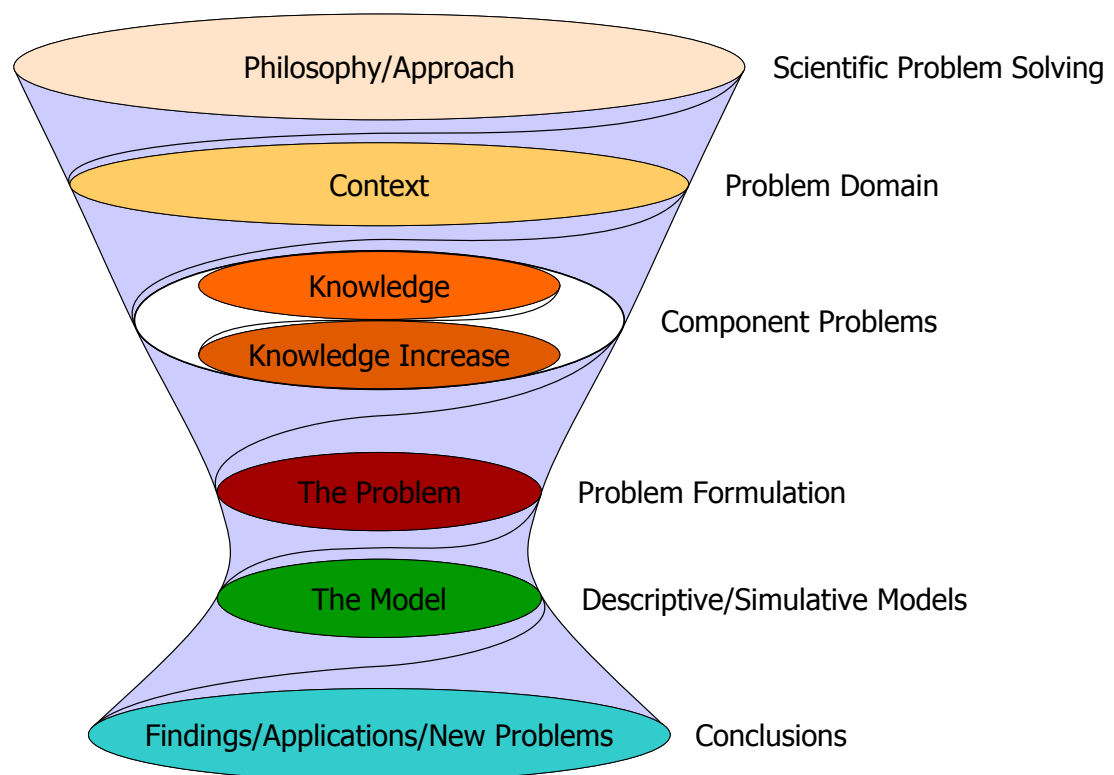
Figure 3: The spiral of discussion: side-view

Most of the dissertation is structured into two-level titles; the first-level titles are called chapters and the second-level titles are called sections. The only exception is Chapter 4, where we have two sub-chapters (second-level titles) and the sections are arranged on third-level. This can be seen at Figure 3, there are two parts on the third level from above, the 'knowledge' and the 'knowledge increase'. As it can be seen

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found in appendices where it can be folded out; throughout the dissertation it is referred to as Appendix 2.

on both pictures the 'hole' is gradually narrowing until we arrive to the 'problem' and the 'model'; these last two are in the centre of Figure 2, and they are of the same width (meaning that the model is supposed to cover the problem). The deepest layer of the 'hole', corresponding to the Conclusions, is wider again, as it considers the possibilities of generalizing the results, their applications, and new problems. This last layer can only be seen on Figure 3; on Figure 2 it is covered and thus invisible.

The spiral starts from the outmost circle (on Figure 2, which corresponds to the topmost layer on Figure 3) focusing on the philosophical and methodological frameworks, which contain a set of pictures about the world of science; beliefs, what is and what is not accepted for this investigation, the methods used along with a rationale is provided. This part includes one supplementary result, a method, which is developed for this inquiry and a problem which is identified in the field of philosophy of science.

The second cycle of the spiral (the second-top layer) getting closer towards the centre is the description of the problem domain; this involves a number of areas from different disciplines that are pertinent to the investigation, and includes several supplementary results and some restructuring of well-known models for the later use. Neither these supplementary results nor the restructuring fall into the mainstream of the development of the results of the present investigation, nevertheless, they are necessary to obtain the main results of the research.

The next cycle on the spiral (the third-top layer) towards the centre involves a more specific description of the component problems, before getting finally to the modelling stage. The definition of the component problems involves a critical and creative discussion of the specific background literature. This part, again, contains a number of smaller results, more or less relevant to the main results but all of them needed for the full picture. A significant achievement of this cycle is the synthesis of the different knowledge-typologies.

There is a chapter about the boundaries of the investigation before really getting to the presentation of models; it is a very short chapter where the limitations of the

inquiry and of the validity of results are summarized, and the problem is, finally explicitly formulated. This is the fourth-top layer on Figure 3.

The modelling stage begins with development of three descriptive sub-models, the Model of Learning Willingness (MLW), the Model of Learning Capability (MLC), and the Model of Attention (MA). These three sub-models are then integrated into a single Model of Learning Ability (MLA), which is the first main result of the dissertation. The descriptive models are then converted into simulative ones, using the Doctus knowledge-based expert system shell, meaning, that the hypotheses are hereby compared to observations and thought experiments. The simulative model is the second main result of the dissertation. The models can be found on the fifth-top level of Figure 3.

This, probably unusual, line of argument is responsible for the fact that the structure of the dissertation may look unusual − but hopefully at first sight only. If we considered everything that happens before the modelling stage to be a background work; the proportion of the 'real' investigation would seem very small. However, as described above, a lot of preparatory work was done in the 'pre-modelling' parts, which is usually presented in the elaboration phase of the result − i.e. the 'pre-modelling' parts not only contain the literature review but also the restructuring of the models from the literature, as well as several subsidiary results.

Also this way of presentation requires significant patience from the reader, as she/he will be asked on more than few occasions to wait until a supplementary result or piece of background knowledge will be used, which may happen a dozen sections later. This is unavoidable for maintaining the above presented spiral line of argument and, in any other structure, the price would be even higher.

2. Scientific Problem Solving

> *"... [the sage]*
> *creates but does not own what he has created,*
> *he acts but does not control,*
> *he accomplishes creation but does not claim credit,*
> *and as he does not claim it for himself,*
> *he does not lose it either."*
>
> *Lao Tzu[1]*

This chapter – the first cycle of the line of discussion (topmost layer on Figure 3) – corresponds to what is usually called 'methodology' in dissertations. There are good reasons for not using the usual term: it is overused and often misused; and this chapter is also not a typical chapter about methodology. It would be more appropriate to speak of a mental framework and the process of scientific problem solving – these two are meant to be indicated by the chapter title.

In this dissertation a postmodern paradigm is adopted, which is in contrast to the reigning positivistic paradigm.[2] This is explained in the first section of the chapter. The subsequent five sections are concerned with the devices/methods used, and explaining in detail the strongly anti-methodological (in Feyerabend's sense) approach of the dissertation. The explanations are twofold: it is explained why some methods are not used (e.g. experiments) and also why some alternative methods are adopted (e.g. phenomenological observations) as well as what kind of assumptions are made. Distinction is made between the way of getting to the results and the evaluation of these results. For both these stages it is explained what is accepted and what is rejected. The last section of the chapter before the chapter summary introduces the process of scientific problem solving as it happened during the present investigation.

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[1] *Lao Tzu (cca. 4. century) Tao Te King, verse 2, my translation, based on the Hungarian translation by Sándor Weöres.*

[2] *Although in the area of investigation positivism is not strong as in some other areas, the interpretivist and various postmodern paradigms are more acknowledged. (e.g. Johnson-Duberley, 2000)*

To speak about scientific problem solving, it is necessary to clarify how the terms *"problem"* and *"problem solving"* are used throughout this dissertation. Simon (1973) distinguished well-structured from ill-structured problems, where the term of ill-structured problems is residual, i.e. ill-structured is what is not well-structured. The criteria for well-structured problems, based on Simon (ibid, p. 183), are:

(1) there is a definite set of criteria to test the solution;

(2) the initial problem state, the goal state and all intermediate states may be represented;

(3) the transitions between the previous states can be represented;

(4) the acquired knowledge can be represented;

(5) the effects of environment can be represented; and

(6) "doable" amount of search and computing is required.

Baracskai (1997) suggests calling well-structured problems *"tasks"* and ill-structured problems *"problems"* (e.g. to avoid misunderstanding with students); this terminology is adopted in this thesis; actually "tasks" are not much mentioned but "problems" always refer to ill-structured problems. We can get a simpler description by rephrasing Simon's six criteria: we can find out that the tasks are to be accomplished and the problems are to be solved. Solution of a problem requires creation of something that did not exist previously.

By accepting Baracskai's terminology we can also avoid the Csíkszentmihályi-Simon debate (Simon, 1988) about the relation between creativity and problem solving. Another additional advantage of the terminology is an easy-to-perceive explanation of the problem structuring as a part or the whole of problem solving, i.e. if at the end of structuring of the initially ill-structured problem only a well-structured task remains to be accomplished, it can be regarded as a solution to the problem. (Eden, 1987)

This chapter is going to introduce the approach to scientific problem solving as it is adopted in this dissertation. The various aspects of the problem solving are exam-

ined in seven subsequent sections, while the eighth describes the process of problem solving as it was employed during the present investigation.

2.1. On Paradigm

> *"Years ago, white settlers came to this area and built the first European-style homes. When Indian People walked by these homes and saw see-through things in the walls, they looked through them to see what the strangers inside were doing. The settlers were shocked, but it makes sense when you think about it: windows are made to be looked through from both sides. Since then, my People have spent many years looking at the world through your window. I hope today I've given you a reason to look at it through ours. Mii gwetch."*
>
> *Marge Anderson, Marge[1]*

There are several reasons why the paradigms should be discussed in a dissertation. First, every dissertation should indicate the paradigm into which its author belongs, as the result is expected to be valid within the same paradigm. This becomes even more important if the author does not belong to the main paradigm of the discipline or if she/he questions some aspects of the paradigm; then it is important to make clear her/his frame of thinking. Second, if there is something unusual in the paradigm, specific to the area of research, it makes it easier to those readers from the neighbouring disciplines to comprehend the dissertation. Third, there may be paradigmatic changes going on within the discipline (or on a greater scale), which are noticed by the author and may affect the process, the result, or the presentation of the problem solving. In this case it is useful to introduce these changes to the reader not only as they can affect the validity of the results but it also shows the author being familiar with the domain. Fourth, the deep involvement into the problem solving process may, as a side-effect, give to the author ideas about tackling problems in philosophy of science, e.g. to identify new problems regarding the conception of paradigms. All the four reasons are relevant here.

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[1] *Marge Anderson, Marge (1999) Looking through our window: The value of Indian culture. Retrieved 01/03/2004 from http://www.clcmn.edu/sfodness/2411/Articles.htm*

Before Kuhn ([1962](#)) developed the conception of scientific paradigms,[1] it was considered that scientific knowledge was continuously accumulated; i.e. that new layers were gradually added to the previous knowledge. This approach is sometimes referred to with the metaphor of the pyramid conception of knowledge (e.g. [Barac-skai, 2000](#), p. 42).

According to Kuhn the scientific disciplines, as they one by one (starting with mathematics, astronomy, physics) separated from philosophy, first were in pre-paradigmatic state. In this period each scientist had to build her/his results "from the basics", using only philosophy as foundation. When a discipline becomes mature (cf. Sections 4.1.8 and 4.2.8), a paradigm forms around it – until then we can speak of an immature discipline. The paradigm determines what can – and must! – be taken for granted, it allows some devices/methods and forbids others, and establishes which problems are relevant for solving ([Kuhn, ibid](#), p. 37). It does not only determine the valid answers but the valid questions as well. It can be said that a paradigm deter-mines how the scientist sees the world through her/his discipline; thus we may call it the window through which one sees the world. Usually there is only one paradigm in a discipline, rarely two. The period, while the paradigm lasts, is called the normal science. The normal science is the time of puzzle-solving, the existing results are fur-ther polished, and nothing radical happens ([Kuhn, ibid](#), p. 52):

"Normal science… is a highly cumulative enterprise, eminently successful in its aim, the steady extension of the scope and precision of scientific knowledge. In all these respects it fits with great precision the most usual image of scientific work. Yet one standard product of the scientific enterprise is missing. Normal science does not aim at novelties of fact and theory and, when successful, finds none."[2]

Sometimes a new conception appears which questions the foundations of the paradigm. This is the time of scientific revolution. As in any revolution, it is not sure that the new idea will win, but there is a fight. This period resembles the pre-

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[1] *Although, the conception is more general, it is applicable to non-scientific disciplines too.*

[2] *All the quotations throughout the dissertation use the original wording.*

paradigmatic science to some extent, inasmuch as scientists often once more go back to build their ideas from the basics.

This dissertation belongs to a postmodern paradigm of cognitive sciences.[1] It is really *a* and not *the* postmodern, as postmodern is, for now, a developing paradigm; thus there is no agreement yet about it. What postmodern scientists agree about is that they all reject positivism (all or parts of it) and that the postmodern comes after the modern. These two paradigms are examined throughout this chapter; with emphasis on explaining what aspects of positivism are rejected and why in this domain of investigation. Being in an underdeveloped paradigm has its advantages and disadvantages for the researcher: On the one hand it is very convenient that she/he can decide what she/he accepts and what not, almost as defining a paradigm for her/his own research. On the other hand, this also requires an acceptable argument, and, as the researcher does not belong to the main paradigm,[2] she/he is subject to more harsh criticism and her/his results are accepted with much more difficulty. It would be reasonable to argue that one should not step out of the main paradigm, especially not in her/his PhD dissertation. However, if one does have a framework of beliefs, one must stick to it to remain convincing – and if one's beliefs do not allow belonging to the main paradigm, one must leave it.

As it was said previously in this section, Kuhn assigned paradigms to disciplines. Lakatos ([1978](#)) argued that the typical descriptive units of examination should not be single theories (as basis of disciplines) but rather scientific research programmes. In the last couple of decades we have witnessed that in cognitive sciences – as in many other areas as well, e.g. in virtually all fields of management – the mono-disciplinary problems have disappeared. We started to use three new terms (based on [Klein, 1996](#)):

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[1] *More precisely, as we shall see later, the results of this dissertation are the most relevant to the field of knowledge management, but during the process of problem solving tools are borrowed from the variety of disciplines.*

[2] *As we shall see later in this section there is an emerging paradigm in the problem domain of the dissertation; however, for now the researchers from the different disciplines are applying the paradigms of their discipline and most of these are positivist, so it can be supposed that the main paradigm is positivism, although this is not strictly accurate.*

(1) Inter-disciplinary problems mean that the problem is considered to be in an empty zone between disciplines, not covered by any of them.

(2) Multi-disciplinary problems are supposed to be examined in their entirety from the point of view of all disciplines involved.

(3) The most recent terminology mentions trans-disciplinary problems, meaning that they are tackled using tools of various disciplines but they are not examined in their entirety from the viewpoint of all these disciplines. Each discipline (or rather tools, methods, models, etc. of each discipline) is used only when it is necessary.

The three terms can be connected in a process of scientific problem solving: We find a problem or, more often, a problem domain, not covered by any discipline, i.e. an inter-disciplinary problem (domain). A multidisciplinary team or, albeit rarely, a researcher with multi-disciplinary knowledge background, attempts to solve it, and they do it in a trans-disciplinary approach. In this dissertation the last terminology is adopted, as the emphasis is on the process of solving the problem.

Now, we can get back to the *cognitive sciences*. Sometimes the term *cognitive science* is used – which is incorrect. If it is said that the cognitive science is a discipline, it is more incorrect. What we are talking about is neither *one* nor a *discipline*. What we are talking about, is a problem domain where a number of disciplines overlap. For this dissertation it is regarded as on Figure 4. What is exciting about this problem domain is that a paradigm is forming around it. It does not mean that we are witnessing a birth of a new discipline, in which case the term cognitive science would be justified, but a formation of a trans-disciplinary paradigm, around a problem domain. So, the cognitive psychologist will remain a psychologist, the artificial intelligence researcher will stick to information systems and the philosopher will not choose another profession. Most of the researchers will also pursue, at some times, other problems in their discipline; but when they are in their joint problem domain, they will share the same paradigm. As this paradigm is still forthcoming, the researchers use a modified version of the paradigms of their own disciplines when working in this particular problem domain, trying to use a common approach. As most of the disciplines, which meet here, have a positivistic main paradigm, the main

approach of cognitive sciences is also positivistic. However, as we only have preliminary paradigm-parts here, not a complete well-established paradigm, the chances for the non-positivistic candidates are better than in most of the scientific disciplines. Another reason for this is that the problems of cognition encounter severe difficulties if trying to be positivistic – as it will be explained throughout the present Chapter. Before concluding this discussion of paradigms, we shall revisit Kuhn's original conception on paradigms and also have an outlook on some new ideas brought to mind during this research, also trying to outline the expected developments in philosophy of science on these grounds.
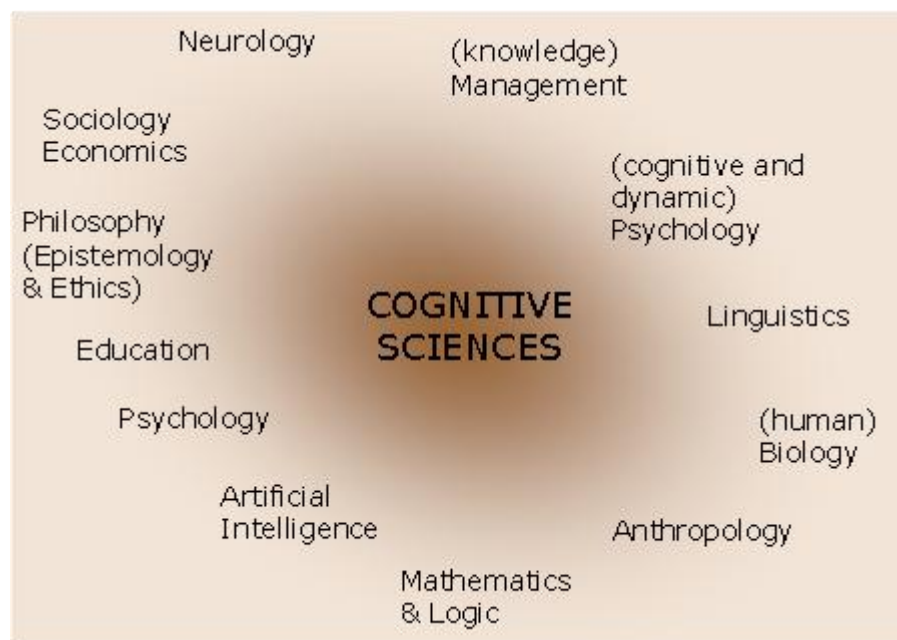
Figure 4: The cognitive sciences.[1]

When Kuhn developed his conception of scientific paradigms he only considered them to have a social dimension besides the trivial knowledge-dimension. He had shown how it is not only a question of knowledge which candidate paradigm is accepted, who wins in the scientific revolutions; on the contrary, in his presentation, sociological factors also play an important role – usually more significant than the knowledge provided by the paradigms. For instance Kuhn (ibid, pp. 157-158) shows that the new paradigm is never superior to the old one in its ability to solve problems;

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[1] *The disciplines are only put there as neighbours around the problem domain of cognitive sciences; their relative position do not indicate any particular relationship.*

it is accepted – amongst others – on the basis of what problem-solving ability it promises rather than on what it demonstrates:

"... less on past achievement than on future promise."

So, the social dimension prevails against the knowledge-dimension. It should also be noted that Kuhn was right – at that time. Times, however, change. There are two changes very important for us: First, thanks to the globalization of science, the members of the whole scientific community in a discipline (or in a problem domain) can/could access each others' results in no time – if they could only have enough time to read all of it. Second, science became a hugely profitable business; by organizing conferences one can make decent money; publishing journals is probably even more profitable, at least if it can be judged by the major publishers' activity. E.g. Emerald Journals (n.d.) publishes more than 150 journal titles in the fields of management and information science; Elsevier has more than 1,800 journals available in Science Direct (2004), meaning more than 4.6 million full-text HTML articles. Also Procter & Gamble has more scientists on its payroll than MIT, Harvard, and Berkeley together. (Nordström-Ridderstråle, 2002, p. 96) These changes have given rise to two additional dimensions of discussing paradigms; today we should include the economical and the political dimension or, in other words, the dimensions of money and of power. These changes and their implication were observed during the present research and, although they do not affect directly this investigation, they are outlined as a problem in philosophy of science waiting for a solution. The described problem will not be examined here in further details; the identification of the problem is one of the spin-offs of this dissertation, and solving it remains for further research. Still, there is something remaining to be said about Kuhn's original conception and some ideas of the followers.

Kuhn, when he developed his conception of scientific paradigms, also established the meta-paradigm of paradigmatic science. The previously-outlined problem of new dimensions that should be included into investigation may be considered as a problem of description only, but the problem that follows is definitely on this meta-paradigmatic level. While he rejected the pyramid conception as a constant accumulation of knowledge, emphasizing that the growth of knowledge also involves decon-

struction and sometimes even change of the place of building, Kuhn still maintained the building-metaphor throughout his book. Capra (1991, pp. 364-365) suggests that this metaphor should also be abandoned, and replaced by the network-metaphor. This would mean not only giving up the presently accepted foundation but the conception of foundation as well. It must be difficult beyond imagination. Only a few times in the history of science have we witnessed giving up some really basic foundations; e.g. Einstein must have needed enormous intellectual courage to question the absolute nature of space and time – a preconception so fundamental, that, before Einstein, we were not even aware of having it. Giving up the conception foundations should result in constantly maintaining a similar state – but if that is a norm not an exception, we can probably get used to it. Capra argues that the network metaphor would also mean a shift from structures to processes; the same shift that was also recognized to be important in business problem solving and was put forward by metaphors of TQM, BPR, and Organigraphs.

In Section 2.7 it will be argued that we should use metaphors instead of definitions in today's turbulent environment. If this conception is fused with Capra's network-conception of paradigms we get dynamically changing networks of metaphors – possibly a forthcoming postmodern conception of paradigms, that should, as was outlined previously, have four dimensions – the knowledge, the social, the economical, and the political.

This section forms the basis of the forthcoming sections of this chapter. The commitment to the postmodern paradigm was established (the forthcoming sections will provide further details and arguments for this). Also two new ideas were recognized in philosophy of science; namely the idea of the web of metaphors and the missing factors of the paradigm-description of Kuhn. These were briefly outlined and together they form a problem that will be an issue for another investigation – it will be acknowledge in the Conclusions.

2.2. On Induction

"Everything that happens once can never happen again. But everything that happens twice will surely happen a third time."

The Alchemist[1]

Induction is a method at the very basis of the positivistic science. A separate section is dedicated to it because of its prevailing usage in spite of rejection by most of the leading philosophers of science, as it is shown through examples here. First the nature of induction and its rejections are described, then it will be explained under which conditions it can be used, into what purpose and with which validity – as it is also done in this investigation.

Induction in logic is a process of getting from particular instances to a general law as opposed to deduction when a general rule is applied to particular cases. (AllRefer Encyclopaedia, 2004) There is a long debate going on among philosophers and scientists beginning from Bacon, the founder of modern inductive method (Russell, 1946, p. 497); but it can actually be traced back to Plato and Aristotle. The argument is about the validity of induction as a proof of a hypothesis.[2] Here are some powerful opinions of high-ranked thinkers about induction:

"... induction is a bodily habit, and only by courtesy a logical process." (Russell, 1948, p. 79)

"I do not believe that we ever make inductive generalisations... I believe that the prejudice that we proceed in this way is a kind of optical illusion... Now all this, I believe, is not only true for the natural but also for the social sciences..." (Popper, 1961, pp. 134-135)

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[1] *Coelho, Paulo (1999) The Alchemist, Harper Collins, London, p. 164.*

[2] *The induction is considered to be a source of valid knowledge, i.e. it is at the same time means of getting to new knowledge and of its validation. The argument considered here is concerned with this second role of induction, which can be understood as a proof of hypothesis..*

The ultimate argument against induction was when Popper (1959) showed that no finite number of observations can prove a hypothesis;[1] as Russell (1948, p. 435) summarized it:

"There is nothing in the mathematical theory of probability to justify us in regarding either a particular or a general induction as probable, however large may be the ascertained number of favourable instances."

If it is so, why do scientists still use induction in their arguments? To get a better understanding of the problem, let's trace its origin in the field of logic following Pólya's (1957, pp. 178-190) train of thought. Syllogism uses two fundamental ways of reasoning,[2] modus tollens and modus ponens. (Philosophy Pages, 2004) The demonstrative (or rigorous) modus tollens is shown in the left column of Table 1, while the induction relies on modus tollens of plausible (also called heuristic) syllogism, shown in the right column of the table.

Table 1: Demonstrative and plausible syllogism

Demonstrative	Plausible
If *A* then *B*	If *A* then *B*
B false	*B* true
A false	*A* more credible

In relation «If *A* then *B*» if *B* is false, *A* is certainly false. However, if *B* is true, *A* can be either true or false. On the other hand, if *B* is true it is not false, which makes *A* more credible (or at least not less credible). Taking a simple example: «If the fuel tank is empty the car does not start.» (If *A* then *B*) If the car starts (*B* false), we can be sure that the fuel tank is not empty (*A* false), however if the car does not start (*B* true) the fuel tank can be either full (*A* false) or empty (*A* true); but it is at least not certain that the fuel tank is full (*A* false), so it can be empty (*A* more credible).

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[1] *Popper (1959) also showed that the principle of inductive inference – if wanting to remain within the same conceptual framework – should also be introduced inductively, which then requires inductive principle of higher level and so on, leading to infinite regress.*

[2] *There are other ways of inference in syllogism, like hypothetical syllogism and disjunctive syllogism but they are all derived from these two. (Philosophy Pages, 2004)*

The major difference between the two kinds of reasoning is that in the traditional modus tollens the conclusion is of the same nature as the premises (i.e. both are clear, sharp) and it is fully expressed and fully supported by the premises (i.e. no additional information modifies the conclusion); while in plausible modus tollens the conclusion is of different nature (i.e. not so sharp but vague), it is neither fully expressed nor fully supported by premises (i.e. the conclusion can be changed if new information is acquired or even without that). It is clear that the conclusion becomes *more* credible but we cannot know *how much more* credible. Using Pólya's (1957, p. 189) description of the demonstrative modus tollens:

"If my neighbor and I agree to accept the premises, we cannot reasonably disagree about accepting also the conclusion, however different our tastes or other convictions may be."

Similarly describing the plausible modus tollens Pólya (1957, pp. 189-190) says:

"… my neighbor and I can honestly disagree how much more credible A becomes, since our temperaments, our backgrounds, and our unstated reasons may be different… the premises constitute only one part of the basis on which the conclusion rests, the fully expressed, the «visible» part of the basis; there is an unexpressed, invisible part, formed by something else, by inarticulate feelings perhaps, or unstated reasons. In fact, it can happen that we receive some new information that leaves our belief in both premises completely intact, but influences the trust we put in A in a way just opposite to that expressed in the conclusion. To find A more plausible on the ground of the premises of our heuristic syllogism is only reasonable. Yet tomorrow I may find grounds not interfering at all with these premises, that make A appear less plausible, or even definitively refute it. The conclusion may be shaken and even overturned completely by commotions in the invisible parts of its foundation, although the premises, the visible part, stand quite firm."

There is, however, something called mathematical induction, which can cause confusion, as it is a method of rigorous proof from mathematics. If we understand the mathematical induction and its relation to inductive reasoning the underlying presumptions of the inductive validation of hypotheses will become clear.

The mathematical induction is applied on a set of items where the ith element can be expressed as function of i.[1] Then three subsequent steps are applied:

(1) check if the hypothesis is true for the first element ($i=1$);

(2) assume that the hypothesis is true for the nth element ($i=n$);

(3) check the validity of the hypothesis for the $(n+1)^{th}$ element using the assumption about the nth element.

As it has been presumed that all the elements of the set can be expressed as the function of their sequential number, these three steps mean a full verification, as starting from $n=1$ all the items are covered. The important part is to understand what is done when this simple logic is applied (to actually perform mathematical induction sometimes requires the highest mathematical skills, however, the logic behind is still simple): using mathematical induction we show that the hypothesis is true for one item and that the validity of the hypothesis does not depend on the variation of the items.

If we apply the train of thought of mathematical induction on induction as a way to prove a hypothesis, we see that the underlying presumption of induction is that the general statement (i.e. the hypothesis) does not change by variation of cases. This presumption falls outside the inductive reasoning, thus validity of induction depends on something outside the inductive inference (Russell, 1948, pp. 435-436):

"If an inductive argument is ever to be valid, the inductive principle must be stated with some hitherto undiscovered limitation. Scientific common sense, in practice, shrinks from various kinds of induction, rightly, as I think. But what guides scientific common sense has not, so far, been explicitly formulated."

This argument also dismisses the induction as a method of proof; on the other hand, it is exactly what gives us the area of application of induction in scientific research. As Ernst Mach has put it (Pólya, 1954, p. 108):

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[1] *Sets of this kind are called sequences in mathematics.*

"Jacques Bernoulli's method is important also to the naturalist. We find what seems to be a property A of the concept B by observing the cases C_1, C_2, C_3, ... We learn from Bernoulli's method that we should not attribute such a property A, found by incomplete, non-mathematical induction, to the concept B, unless we perceive that A is linked to the characteristics of B and is independent of the variation of the cases. As in many other points, mathematics offers here a model to natural science."[1]

What is then the area of application for induction? By observing particular instances we can discover a general relation but we cannot prove its validity the same way. Induction is a useful source of ideas but it is valid only if the general statement does not vary by variation of the instances. In mathematics, induction leads the researcher to the idea and then it is proved using mathematical induction; in this sense, the mathematical induction is actually complementary to the inductive reasoning. That is why Pólya ([1957](#), p. 190) says:

"Heuristic reasons are important although they prove nothing."

Popper ([1959](#), pp. 7-9) also limits his argument to the proving power of induction, the *"logic of knowledge"* as he calls it, as opposed to the *"psychology of knowledge"*, which deals with the ways of getting to the ideas on which the scientific results are based. He allows all ways of getting to new ideas ([Popper, 1959](#), p. 8):

"... there is no such thing as a logical method of having ideas, or a logical reconstruction of this process. My view may be expressed by saying that every discovery contains «an irrational element», or «a creative intuition», in Bergson's sense."

What do we do if we draw a general conclusion on basis of finite observations? We extrapolate the relation from the observed items to the whole set of them.[2] The trouble here is that extrapolation is known as probably the most unreliable method of

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[1] *Pólya ([1954](#), p. 111) notes that Mach believed that Jacques Bernoulli had invented the method of mathematical induction but it was actually invented by Pascal.*

[2] *In this train of thought we do not use sampling techniques in induction, which raises the problem of representativeness discussed in the next section.*

mathematics[1] and it is also proved to lead nowhere in various disciplines. In philosophy Russell's ([1959](#)) example became famous as 'Russell's chicken' and perhaps the strongest argument comes from finance, known as the weak form of market efficiency ([Fama, 1970](#)).

What can justify us in saying that an observed relation does not depend on the variation of cases? Well, we have nothing else to rely on but the experience, the knowledge of the researcher – and it is bad news for the defenders of the objectivity of scientific pursuit: the experience is subjective. This means that we have to give up the objectivity (in the sense of being non-subjective) if we want to use induction. The greater the knowledge of the researcher in the domain the greater is the chance that she/he can 'sense' whether the observed relation is only true for the observed instances or it is a more general one. Of course, that 'sensation' does not constitute rigorous proof but it may be true nevertheless.

As it will be argued in Section 2.4 we have to be subjective in the present field of investigation anyway. If we accept the subjective nature of our knowledge we have no reason not to use induction, that is to say our experience, as a source of new ideas – of course they cannot be considered proved. In Section 2.5 a special form of induction is developed, which was used in the present investigation.

2.3. On Observations

> *"Experience never fails. It is only our judgment which fails, seeking in our experience things which experience is not able to provide."*
>
> *Leonardo da Vinci[2]*

The previous section discussed under what conditions we can make use of induction; that, if we allow subjectivity then induction can be a way or part of the way getting to results. To use induction, we need some kind of input from the reality. This

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[1] *If a function is observed in a certain domain we should guess its behaviour outside that domain – a rather unpromising enterprise.*

[2] *Da Vinci, Leonardo (n.d./2002) Prophecies, Hesperus Press, London, p. 34.*

section is concerned with the question of how to get this input. As scientific results are always about the reality, this input is important not only if we use induction but, at some stage, in all kinds of scientific research.

In natural sciences a common way for getting input from reality means conducting experiments. Experiments in a Galilean sense mean isolation of a part of the reality and keeping some of the parameters of this part of reality under control, while those parameters that are not under control are neglected. Therefore the experiment is supposed to represent the reality. The idea of controlling all the parameters is based on the presumption that all these parameters are measurable. Then an event is observed in this controlled environment; and this observation means measuring the changes of the parameters, thus the experiments in this sense are supposed to be non-subjective. They are independent from the experimenter. The observation could be repeated countless times, by anybody, and the outcome would always be the same.

There are two aspects from which this conception could be asserted. The first is that experiments are also designed based on some ideas, some hypotheses. (Popper, 1961, p. 98)

"I believe that theories are prior to observations.... I do not believe, therefore, in the «method of generalization»... I believe, rather, that the function of observation and experiment is the more modest one of helping us to test our theories..."

Without preliminary ideas, the experimenter would not know what to measure, how to isolate the part of the reality, or what event to observe. This means that experiments are not sources of new knowledge but a way to increase the reliability of existing knowledge. This is an important role, so what was the reason to present experiments as something else? (Roszak, 1948, p. 103)

"In Galileo's day, the dominant ideas about nature were derived from a few sacrosanct authorities – either Christian theology or Aristotle. In order to free themselves from this increasingly restrictive heritage of tired, old ideas, these daring minds were moved to call ideas themselves into question. So they recommended a new point of departure, one which seemed innocuously neutral and therefore strate-

gically inoffensive to the cultural authorities of the day: they would concentrate their attention on the clearcut indisputable facts of common experience – the weights and sizes and temperature of things. Facts first, they insisted. Ideas later."

The second assertion comes from quantum physics. In experiments it is assumed that there is a reality 'out there' and the experimenter observes it without being involved. However, as quantum physics has shown us, this assumption is not valid. The elementary particles demonstrate both wave and corpuscular characteristics – which are mutually exclusive. Which one will be manifest depends on the experimenter – none has any meaning outside the experimental context (Davis, 1989, p. xiv):

"One experiment may reveal the wave nature of the electron, another the particle nature. Both cannot be manifested at once; it is up to the experimenter to decide which facet to expose by his choice of experiment."

So, even in quantum physics we cannot observe the reality without affecting it, as, e.g., described by the thought experiment known as Schrödinger's cat. The experiments, the measuring devices are designed by the experimenter, the experimental data are interpreted by the experimenter, and so on (Heisenberg, 1962, p. 25):

"... we have to remember that what we observe is not nature in itself but nature exposed to our method of questioning... quantum theory reminds us, as Bohr has put it, of the old wisdom that when searching for harmony in life one must never forget that in the drama of existence we are ourselves both players and spectators."

This second assertion gains further importance when we need input from reality about people; as it will be shown in the forthcoming systematic analysis of the presumptions of experiments in relation to research about human beings. Once these general characteristics of experiments are examined from the viewpoint of human research, the next step will be to examine those issues that do not even emerge in investigations of inanimate nature and only do so weakly in investigations of sub-human living organisms, such as moral considerations.

Humans are immensely complex and they live in the web of other humans and human organizations, thus all the parameters and their interrelatedness cannot even be mapped, it is difficult to keep them under control, and it is impossible to see which can be neglected. This is already enough to pose the question, whether it is at all possible to use experiments in human affairs. There is an idea, how this difficulty could be overcome: When you believe that there is a single factor variation of which causes changes in another parameter, get this single factor under control and use a representative sample in relation to all the other parameters. (Aronson, 2004, pp. 332-338) There are two notes to be made on this approach. Firstly, to establish control over the examined factor, a laboratory environment is needed, which means artificial isolation of a part of the reality (just as in natural sciences) resulting in exclusion of some environmental influences; as we are not aware of all influences we cannot be sure that we have not excluded something crucial. Secondly, for the same reason we also cannot be sure that we really have a representative sample in relation to all the other parameters.

Kvavilashvili and Ellis (in press, cited in: Eysenck, 2001, pp. 4-5) discuss these two remarks under the topic of ecological validity, which consists of two parts: (a) representativeness (natural situation vs. experimental situation); (b) generalisability (validity of findings in real world). The authors claim that psychological experiments lack ecological validity on both aspects. Aronson (ibid) acknowledges these and offers random assignment (anybody can participate the experiment) to give acceptable approximation from the viewpoint of the second remark while for the first he emphasizes the importance of the design of the experiment, which, as he argues is more art than science. He also says that (ibid, pp. 339-340) experiments can be realistic in two different ways: *experimental realism* refers to people really displaying what is observed if the experimental situation would happen in the real world; *mundane realism* means how much the experimental situation reflects the real world. High experimental realism is achievable while we can never be sure about mundane realism.[1] Important conclusions can be drawn based on high experimental realism alone; this

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[1] *Actually we can often be sure that such situations as in the experiment never occur in real life but we cannot be sure if the seemingly high mundane realism is really high.*

is how Aronson and some others became such successful experimental psychologists. But, as in the case of induction, it is more because of these exceptional individuals than because of the experiment (Slater, 2005, p. 53):

"Picture a scientist discovering a new antibiotic that works amazingly well on male rats in super-sterilized cages with one testicle only. That discovery lacks external validity, for most men have two testicles and, as a general rule, keep their living conditions less than sterile."

Another way of coping with the impenetrable diversity of parameters in human experiments is to use a control group – as is often done – for which everything is the same (or at least the experimenters try to make everything the same), so it is supposed that all the differences of the outcome are caused by the difference of the controlled parameter. This assumption may be asserted in terms of questioning the 'control' feature of control groups.

The next thing that does not work in human experiments is the repeatability. When we perform the experiment for the first time we change the starting conditions. This means that the *same* experiment cannot be performed ever again. We either have to face the situation or we have to work with different experimental subjects. So, we have only a single opportunity in case of human experiments.

All the features discussed so far that are specifically human are about the variety of parameters in some manner. To cope with this, human experiments are usually conducted with a number of people at the same time, trying to achieve representativeness. Of course there is one limitation to the representativeness which surely remains: only people willing to participate in such experiments will be represented – usually they are students from the university at which the experimenter works. This all also means that huge effort and usually collaboration of many people is needed, which also means a lot of time and a lot of money.

There are two further sources of subjectivity also involved in human experiments: (1) The parameters are often not measurable, so the changes of the parameters need to be interpreted (this is, of course, often true in case of measurable parameters as

well but the interpretation of immeasurable parameters leaves more space to individuals). (2) The experiments are not carried out with objects but with human beings, who think, feel, may be in different moods, have different beliefs, etc. This is why in human experiments we do not talk about experimental objects but of experimental subjects.

Having human beings for experimental subjects involves a series of wholly new considerations as well. How to get people to be in similar moods (and the similar moods may still be something very different to different people); what would be the same situation for people with different beliefs and different value systems, and so forth. But most of all, the situation becomes complicated when we take the moral issues into consideration. To get as close as possible to natural context, the experimenter usually deceives the people volunteering to participate the experiment. After the experiment the experimenter explains to the participants what has actually happened and what the inquiry was about, and the participants agree, with hindsight, that they were willing to participate. Sometimes things go wrong, and there is not only a need for explanation but the participants also need psychological treatment. Two extreme and well-known examples are introduced here.

A disastrous example of the deception was the obedience experiment of Milgram (1975). An experimenter, a fake experimental subject and a real experimental subject participated in this experiment. The experimental subjects were told that the inquiry is about the effect of punishment on learning; one of them was going to be the learner, the other the teacher. They draw, and the real experimental subject always got the role of the teacher. The experimenter instructed the teacher to administer electroshocks to the learner every time she/he made a mistake, increasing from the beginning 15V to 450V (30 grades, the high grades labelled "Danger: severe", "XXX", etc.). The learner started to complain at 150, gave a last scream at 300 and then went silent. The experimenter said that the silence was to be considered a wrong answer and the shocks were to be continued. How many people went "all the way"? 65%. Of course, they were debriefed when the experiment ended. Was it enough? (Abelson-Frey-Gregg, 2004, pp.256-257)

"Most seriously, he led them to believe that they were perilously harming another human being. Even after a friendly reconciliation with the supposed victim and a thorough debriefing, participants were left forever knowing that they were capable of such perniciousness."

As one of the experimental subjects said decades later (Slater, 2005, p. 49):

"I was in the lab, and I only went to 150 volts. If I'd gone any higher, believe me, I wouldn't be talking to you right now. That would be between me and my psychiatrist."

The second example was the Stanford Prison Experiment conducted by Zimbardo (1999-2005). The experimental subjects were told that they would be assigned the role of a prisoner or the role of a guard. The deception was small at this time: the guards were told that the experiment focuses on the prisoners but they were also under surveillance. In this case the deeper deception was created by the illusion of the jail. The scene was set in the Stanford County Jail. Even Zimbardo, impersonating the prison superintendent, started to think more of how to prevent an assumed escape than how to run the experiment. The guards had to recognize that in such a situation they (or more precisely some of them) were capable of becoming violent, exercising their power and so on. But there was another reason why the experiment ended after only six days instead of the planned two weeks. Using Zimbardo's (Haney-Banks-Zimbardo, 1973, p. 69) summarizing words:

"The prisoners experienced a loss of personal identity and the arbitrary control of their behaviour which resulted in a syndrome of passivity, dependency, depression and helplessness."

Both experiments could be further analyzed, but probably this brief description is enough to make the point: when undertaking experiments with people we shall inevitably affect them. Carefully planned, very expensive experiments involving work of a lot of people and requiring a lot of time can be carried out – but this is definitely beyond the possibilities of a doctoral project. There are other ways of getting input from reality. Experiments can be considered as a direct mode of getting input from

reality, i.e. the researcher is directly observing what is going on during the experiment. Another direct way is if the researcher does not artificially isolate a part of reality but performs *observation in natural context*. There are some more or less structured versions of this kind of observations, e.g. variations of action research. In human domains we can also have indirect inputs from reality, i.e. we can survey people in the form of questionnaires and interviews (which may be more or less structured) or we can simply talk to them. Some unstructured ways of getting inputs from reality are examined in further details in the next section.

There is a special branch of inquiry called thought experiments. There are two major types of it: In the first we devise an experiment that cannot be performed (1) for now due to e.g. technical difficulties but it may be possible to perform it at some time in the future; (2) for an overriding consideration, e.g. ethical considerations, apart from which in principle, it could be carried out. In both cases we think about what the outcome of the experiment would be if our knowledge is right. Probably the most famous thought experiment is the Einstein-Podolski-Rosen (EPR) effect (Penrose, 2004, pp. 582-591). It was originally imagined by Einstein, arguing against non-local variables, he said, that if the argument of quantum physicists was right, it should have such and such an outcome. A slightly modified version of the experiment was carried out years later, when the technology became advanced enough, and the outcome was what Einstein had predicted. The second type of thought experiments is often used by Gestalt psychologists. In this type we relate our experience and/or well-known phenomena to our hypothesis, e.g. if our model is correct, in such and such situation we should observe such and such outcome – is this what our experience says? Of course, as in the case of induction, we have to give up the requirement of non-subjectivity to use this second type of thought experiments – it is also based on experience, which is subjective.

In the present dissertation, exclusively unstructured inputs are used from the reality, partly as direct observations and partly as talking about it and performing thought experiments of the second kind. This is coherent with the postmodern nature of the present investigation, as it was declared in Section 2.1. Some features of this kind of

input from reality are discussed in the next section with the necessarily subjective nature of it in focus.

2.4. On Qualia

> *"Grown-ups love figures. When you describe a new friend to them, they never ask you about the important things. They never say: «What's his voice like? What are his favourite games? Does he collect butterflies?» Instead they demand: «How old is he? How many brothers has he? How much does he weigh? How much does his father earn?» Only then do they feel they know him."*
>
> *The Little Prince[1]*

The basic means of getting input from reality were introduced in the previous section, examining experiment in detail. It has been argued that it is rather difficult to conduct experiments in human domains and it requires a lot of money, a large trained crew and a long time – these requirements are definitely far beyond possibilities of the present investigation. Another direct investigation, observation in natural context was used instead, combined with indirect survey (namely thought experiments). This means reduced controllability and increased subjectivity in favour of being more realistic. Both the observations and the thought experiments were focused on qualia, the subjective experiences during the knowledge increase. In the present section the conception of qualia is examined from the phenomenological and hermeneutical points of view as ways of getting input from reality.

The term *"qualia"* (singular *"quale"*) was first used by Lewis (1929) in its modern sense. It signifies the subjective nature of experiences: i.e. that when we experience something, a phenomenon, this experience can only partly be described by the objective terms; there is always a part of our experience that appears in our consciousness, accessible only via introspection and describable only in subjective terms (Eliasmith-Mandik, 2004):

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[1] *Saint-Exupéry, Antoine de (1995) The Little Prince, Penguin Books, London, p. 16.*

"A quale is an introspectible and seemingly monadic property of a sense-datum. For example, the qualia of a visual sense-datum of a rose would include the experienced red-ness, and the qualia of an olfactory sense-datum of a rose would include the sweet-ness of the scent."

On reading the literature there appears to be two interrelated domains engaging into qualia: phenomenology and hermeneutics. Phenomenology is a field of philosophy like ethics, logic, ontology/metaphysics, epistemology, which was started as movement in the first half of the 20th century by Husserl, Heidegger, Merleau-Ponty, Sartre, and others (Smith, 2003). Their starting point was that our experience always has a part which cannot be transferred to one who has not experienced it – this part is called qualia. Therefore, the experiences can only be investigated from first person perspective, i.e. using introspection. All the investigations considering human consciousness should use this approach. Hermeneutics, in its modern sense, focuses on interpretation, which cannot be divorced from the context. Originally it was concerned with interpretation of texts, primarily sacred texts; in its modern sense it is formulated by Gadamer (1977) and it is concerned with achieving the meaning through interpretation; it links further to Weick's (2001) conception of sensemaking in organizations. Thus, the topic of qualia is the area of overlap of these two domains.

The concept of qualia is probably easiest to understand using Jackson's (1982) famous thought experiment about Mary and the rose. Mary was grown up in a completely black-and-white environment; she was never allowed to leave her room and to see the nature. She has never seen any colour apart from black and white. She has been educated about the colours, about the perception, about the biology of seeing. She has learned everything that can be learned about the colours from others without actually experiencing anything in colour. Then she leaves her room, sees a red rose and passes out. There is something that cannot be explained, something that is to be experienced personally.

The concept of qualia makes the difference between the monistic and dualistic approaches to the world; and thus it is a topic of heated debates. A long time ago it was

easy to distinguish between these two approaches; the Church vs. the science. (See e.g. the quotation from Roszak's in the previous section.)

Monism has two basic (and opposite) kinds: according to materialism everything is of material substance, there is nothing else; according to idealism only the world of ideas or the spiritual world is real, everything else is a deception. There are also two variations of dualism: the substantial dualism distinguishes two kinds of substances, the matter stuff and the mind/spirit stuff (i.e. the body and the mind/spirit); the property or functional dualists say that there is only one kind of substance but with two different kinds of properties, material and mental respectively. The situation is further complicated with the in-between-approaches, e.g. some materialists would allow that something emerged from the material substance that cannot be reduced to material anymore and, similarly, some idealists would accept that there is matter which appeared as materialization of ideas. The dualists also became divided about which is the primer substance (or property group), the material or the spiritual. All these approaches debate about qualia.

The two extremes are the reductionist-type materialists and the substantial dualists. The reductionists claim that qualia are reducible to neural processes and thus they actually do not exist; if we would tell Mary really everything about colours and the neural processes producing the states of consciousness about the 'redness' she would not be surprised at all when seeing the red rose. She would exactly know what it is like to experience it – thus there is no room for qualia. It is just that we do not know enough yet about the brain-processes that produce consciousness. But we will find it out! – they argue. Famous representatives of the reductionist approach in investigation of mind and probably its most forceful defenders are Dennett (1993 and 1995) and Damasio (2004). The substantial dualists believe that qualia exist as an essentially distinguishable quality as there are substances of non-physical nature. Probably there are new kinds of substances, i.e. non-physical ones, still to be discovered to get to the understanding of consciousness. Whatever we teach Mary, she cannot know about the rose without seeing it. Well-known representatives of this approach are Penrose (1989 and 1995) and Chalmers (2003).

This dissertation does not aim to take part in this debate or to get involved in it. This dissertation aims to produce a model on knowledge increase, and it aims to do it now, not at some future time when our knowledge of the biology of brain increases enough to explain the consciousness (i.e. if it can be explained by the biology of brain). Therefore, the phenomenological-hermeneutical conception of qualia is adopted, as, at least for now, it seems to be the only way of engaging in modelling of human knowledge; this is how the subjectivity comes into the picture. Together with this conception of qualia the relevance of the first person point of view is also acknowledged. This is the reason for using the already mentioned way of observation; further details are discussed below.

If we try to distinguish in a phenomenon what can and what cannot be described in non-subjective terms, we will see that we can describe non-subjectively only what we can measure. We have an independent, non-subjective measure to which some parameters of the phenomenon are compared, this does not leave any space for debate, we have nothing else than to accept the result of measuring. However, even the results of measuring need to be interpreted (as it was already described in the previous section from a different perspective) which, according to the accepted approach of hermeneutics, involve qualia. The quantum physics teaches us also that the observer has an effect on the observation, which is a further source of subjectivity (Heisenberg, 1962, p. 19):

"This looks as if we have introduced an element of subjectivism into the theory, as if we mean to say: what happens depends on our way of observing it or on the fact that we observe it."

In human-related domains there are few things to measure and those are usually not very important. We must not confuse the parameters we measure with the features of the phenomenon we are interested in. When we e.g. measure the number of returned items as we are interested in the quality of those items, we do not measure the quality, only a parameter which we suppose to be correlated with the quality. What we do do, we subjectively interpret the results of measurement to make inference about the quality. As Checkland (1999a, p. A40) says:

"But the system thinker also accepts that an observer, investigator or researcher will not only select the level which is to be that of «system» but will also interpret the nature of «system» according to his or her own Weltanschauung or world-view…"

So, there is almost nothing that we could reasonably argue not to be subjective in our investigations about humans. Does this also mean that our investigation is not objective? This can be argued both for and against. If by objectivity we mean non-subjectivity, then it is true, we cannot be objective (Polányi, 1962a, p. 18):

"… complete objectivity as usually attributed to the exact sciences is a delusion and is in fact a false ideal."

Why we do not just throw away this false conception of objectivity? It makes the lives of scientists and philosophers so difficult! Why Kuhn (1969, pp. 186-187) feels that he has to defend himself against "being accused to praise subjectivity"? His argument against this could actually be translated something like: "the researcher's work is subjective indeed − and this is not a bad thing". Why even Polányi (1962a) repeats again and again that the personal knowledge of the researcher is not subjective, although, it is not objective either. The answer is that we have believed that if something is subjective then it is not objective. Objective means that it is about reality. The science explores reality; its highest aim is to provide us with better and better (supposedly once a total) understanding of reality. Thus, if objective and subjective make a dichotomy, being subjective is wrong. But subjective does not mean non-objective! The knowledge of reality is objective. The knowledge of someone is subjective. Thus someone's knowledge of reality is objective and subjective at the same time.

Only if we accept these conceptions of objectivity and subjectivity we can proceed with using phenomenological observations and the conception of qualia. The observation cannot be divorced from the observer, thus it is subjective (apart from measurement but it is not applicable in the present research). If we accept these, the first person viewpoint can be used for getting input from reality. Two versions of observation were used during this research, both of them in natural context. The first is self-observation, when the researcher observes herself/himself in particular situa-

tions. Maslow regarded self-observation as particularly important (quoted in Geiger, 1971, pp. xv-xvi):

"We must remember, that knowledge of one's own deep nature is also simultaneously knowledge of human nature in general."

This kind of observation is first-hand phenomenological observation in a natural context. A second-hand observation of the same kind would be if the researcher observes others and draws conclusion from these observations. In this case we could talk about meta-qualia, as the result of the observation is the researcher's qualia about the qualia of others. The third-hand observation would be if someone else is observing others and then reports about this to the researcher. The combination of the last two makes sense if the third-hand observer and the researcher, i.e. the second-hand observer, have both deep understanding of the area of research and they discuss their experiences. This discussion, due to the hermeneutic nature of qualia, can lead to better understanding of the reality, which was observed. All the three versions of phenomenological observations were applied in the present research.

This kind of inquiry takes into account all the aspects of subjectivity but, as it was presented so far, it does not do better from a moral perspective than the experiments; i.e. those observed did not agree to be observed, although, they are not affected by the research, so no harm can be done. However, the moral aspect of the present research is stronger than how it can be seen at the moment. The observations were unstructured, so it was not planned in advance, what will be observed. All the discussions regarding the observations happened after the actual events, and no records were made to maintain the unstructured nature of the observations and to keep the outcomes of the discussions in the focus – these were immediately built into the on-going research polishing the model further. One may object that the people observed still did not agree to be observed. However, this objection would mean the same as if we would object to people learning from the events they are participants of, from their experiences. As the discussion of the observation happened with hindsight, the aspects of observations were not fixed in advance, rather, what was going on was observed – there actually was nothing the observed people could be asked to agree to. This would attach two further epithets to the previous ones, so the proper name for

the input from reality in the present dissertation would be *ex-post, first-, second-, and third-hand, unstructured phenomenological observations in natural context*.

In addition to these observations thought experiments were also frequently used, based on the same observations or other personal experiences or well-known phenomena, as it is often done by the Gestalt psychologists. How were these observations and thought experiments carried out? Simply, the scene setting given by circumstances was used.

> *My mentor Zoltán Baracskai was asked to conduct a course on philosophy of science for the PhD students at the department, which meant nine of us. We called it the Apprenticeship School. The course has taken place in the period when I was working on my PhD research. After the group meetings my mentor and I occasionally discussed our experiences of the Apprenticeship School. As we were also discussing the progress of my PhD research, it was natural to relate the two. So, we started to test the hypotheses of my research using observations from the Apprenticeship School. We also often designed ad hoc thought experiments to explore: "… in such and such situation the model from my research predicts such and such outcome for XY – is this what would happen?"*

This way the observations and the thought experiments (partly also based on experience from the Apprentice School) were the means of testing the models during the research. These, with hindsight, became the three versions of input from reality as described previously: *ex-post, first-, second-, and third-hand, unstructured phenomenological observations in natural context*. In Chapter 6 two cases of such testing are described in detail as illustrative examples.

The applied modes of getting input from reality have high mundane validity simply thanks to the natural context of the observations. It was explained previously that the repeatability cannot be expected even from experiments if they are conducted with people instead of objects. This also cannot be claimed for the observations used here. However, Checkland ([1999a](#), p. A40) offers a substitution for this requirement, the recoverability:

"This means declaring explicitly, at the start of the research, the intellectual frameworks and the process of using them which will be used to define what counts as knowledge in this piece of research. By declaring the epistemology of their research process in this way, the researchers make it possible for outsiders to follow the research and see whether they agree or disagree with the findings. If they disagree, well-informed discussion and debate can follow."

This whole chapter is about satisfying the requirement of recoverability, which appears to be a more appropriate criterion in the present approach to scientific problem solving than repeatability. Now the account is given about how input from reality is obtained. The following two sections are focused on the next step, i.e. what is done with these inputs from reality.

2.5. On Method

> *"What is the difference between method and device?*
> *A method is a device which you use twice."*
>
> The traditional mathematics professor[1]

Besides getting inputs from reality, during the process of scientific problem solving, we also make inferences – not necessarily in this order. The inferences, the thinking in the research may be grouped into two large categories: inferences made to get us to the solution and the inferences made to justify that the results should be accepted. Popper (as it was already said in Section 2.2) calls the first group psychology of knowledge and the second the logic of knowledge. Both are essential for understanding the process in which the results of this dissertation were achieved. The present section focuses on the logic of knowledge, dealing with the psychology of knowledge only partially, to the extent that is necessary to overview the different paradigms of epistemology. The way of getting to the results is the creativity; this is in the focus of the next section.

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[1] *Pólya (1957, p. 208) quotes the traditional mathematics professor of the popular legends, whose sayings are handed down from generation to generation.*

Epistemology is a branch of philosophy dealing with knowledge, more precisely how we come to know what we know. Thus the central theme of epistemology is the validity of knowledge, so, finding the criteria of validity of knowledge. The relevance of epistemology for the present dissertation is twofold: Firstly, as any dissertation is a new knowledge, epistemology is a necessary area of any dissertation and thus for the present one as well. Secondly, this dissertation is about knowledge increase, thus epistemology is also relevant as its central topic. For better understanding of the epistemology today, a short historical overview is also given; not aiming for totality only for providing a background for the forthcoming argument.

There are two roots of today's epistemology:

1. Empiricism has the word "British" as one of its usual attributes as it was primarily the pursuit of British philosophers. It can be traced back to the work of Bacon (1620), who saw the role of science as enabling human domination of nature and who also invented induction (cf. Section 2.2). Locke (1690) added the conception of *"tabula rasa"*, i.e. that any valid knowledge can be traced back to a simple sensory perception. The line of great figures of empirism continues through Hobbes and Berkeley to take its final form in Hume. Hume doubted induction and causality; he distinguished between impressions and recollections of impressions (ideas), claiming that the latter can be false. According to Bower and Hilgard (1985, pp. 2-4) empiricism has the following features: sensationalism (all knowledge comes from sensory experience), reductionism (complex ideas are reducible to simple ones), associationism (ideas are connected through associations of experiences that occur closely together in time), mechanism (mind is – at least like – a machine).

2. Rationalism wears the epithet of Continental, as opposed to British empirism, being primarily pursued by overseas philosophers. It begins with Descartes' (1637) quest for knowledge using infinite doubt, which led him to realize that if he could doubt everything, he was actually performing the act of doubting; so he cannot doubt that he doubts, that is he cannot doubt that he thinks – *"cogito ergo sum"*. This became the first principle of Des-

cartes' philosophy (p. 27), while at the end of the next paragraph we can find his second principle, i.e. that there must be some *"I"* that doubts, which is *"wholly distinct from the body"*. This second principle became known as the Cartesian division or the mind-body problem (cf. Section 2.4). Although rationalism can be regarded as fully developed by Descartes, there are others in providing important contributions, such as Spinoza (Russell, 1946, pp. 521-530), *"the noblest and most lovable of the great philosophers"*, who added the moral perspective, Leibniz (ibid, pp. 531-543), who draws powerful conclusions about nature based on speculations and could have become the founder of mathematical logic if he had published all his writings, Kant (ibid, pp. 637-651), who derived all knowledge from his "a priori categories", and Hegel (ibid, pp. 661-674), who developed the conception of the *"Absolute Idea"* combined with his dialectic (thesis-antithesis-synthesis).

Historically, Comte coined the term *"positivism"* to rid science of dogmas of the church (Johnson-Duberley, 2000, p. 20), to identify the scientific or positive knowledge, which is useful and certain. He used key concepts of Descartes' rationalism and Hume's empirism. J. S. Mill declared that the *"nature is uniform"* (ibid, p. 21) thus the identified causal relations can be extrapolated, so justifying the induction – and his own inductive methods. (cf. Section 2.2)

The form of positivism that is most known today is the logical positivism or logical empirism of Vienna Circle, mostly by work of Carnap and Ayer. (Ayer, 1946) There are slightly different interpretations of logical positivism but there are four major characteristics, which are never questioned (Johnson-Duberley, 2000, p. 23-27):

1. Science is based on neutral, value-free, objective observations made by the passively registering scientist from outside the phenomenon, using neutral language derived from Descartes' rationalism.

2. Subjectivity is rejected; everything has to be empirically tested (which is claimed to be non-subjective).

3. Methods of physics should be used: as the causation itself cannot be observed we also should not try or require that.

4. The general objective is to enable prediction and control of nature and society, so the knowledge becomes instrumentally useful.

Bertalanffy rejects the epistemology of logical positivism (1969, p. xxii):

"The epistemology (and metaphysics) of logical positivism was determined by the idea of physicalism, atomism, and the «camera-theory» of knowledge. These, in view of present-day knowledge, are obsolete. As against physicalism and reductionism, the problem of modes of thought occurring in the biological, behavioral and social sciences require equal consideration and simple «reduction» to the elementary particles and conventional laws of physics does not appear feasible."

Positivism also means that in this paradigm the new knowledge is accepted on basis of positive verification. It was already shown (Section 2.2) that positive verification is impossible; here it is shown based on Popper and others how positivism can be ultimately rejected. Regardless of how many supportive evidences we line up we can never claim that a hypothesis is positively verified; there is always a chance that we will find a disproof. The positivism, as it was also said previously (Section 2.4), is also cult of objectivism (meaning non-subjectivism), and thus the positive verification is expected to be non-subjective (Polányi, 1966, p. 25):

"... it is futile to seek for strictly impersonal criteria of its validity, as positivistic philosophies of science have been trying to do for the past eighty years or so. To accept the pursuit of science as a reasonable and successful enterprise is to share the kind of commitments on which scientists enter by undertaking this enterprise. You cannot formalize your commitment, for you cannot express your commitment non-committally. To attempt this is to exercise the kind of lucidity which destroys its subject matter. Hence the failure of the positivist movement in the philosophy of science."

The ultimate hit positivism receives is from Popper (1959) who refutes the possibility of positive verification with sound arguments and a number of examples. He remembers it the following way (Popper, 1992, p. 99):

"Everybody knows nowadays that logical positivism is dead. But nobody seems to suspect that there may be a question to be asked here – the question «Who is responsible?» or, rather, the question «Who has done it?»… I fear that I must admit responsibility. Yet I did not do it on purpose: my sole intention was to point out what seemed to me a number of fundamental mistakes… Some members of the Circle were impressed by the need to make changes. Thus the seed were sown. They led, in the course of many years, to the disintegration of the Circle's tenets."

Some positivists today claim that Popper actually improved positivism (Johnson-Duberley, 2000, p. 27 ff) but this assertion is best left to the taste and formulation of the reader. Instead of proof, the positive verification, Popper (1959) suggests a hypothetico-deductive method and falsification, i.e. negative verification. According to the conception of falsification anything can lead to scientific result; when we achieve it, we can put all our efforts to falsify it. If it cannot be falsified we can temporarily accept it. The falsifiability also became the criterion of demarcation, i.e. between science and non-science. New knowledge can be considered scientific exclusively if it can be tested and falsified; if new knowledge cannot be falsified it does not belong to domain of science but of pseudo-science, such as religion, superstition, or Marxism. (Popper, 1992, p. 42 ff)

This idea can be questioned. If one reaches a new result one is not in the best situation for trying to prove it being wrong. Firstly, there is a psychological inadequacy, meaning that after having put effort to achieve the new result we can hardly have a real desire and commitment to show that it is wrong. This does not contradict the requirement to consider our results temporary; we may even refute some of them later if we have a better (whatever this means) solution. Secondly, there is a cognitive inadequacy, which means that achieving a result requires a different mindset from falsifying it. So it is better to leave falsification of our results to others; they, of course, have to understand it first.

Kuhn (1962) embraces Popper's idea to reject positive verification but he rejects falsification too. New knowledge, a possible source of a new paradigm, is compared to observations constructed, interpreted, and accepted in the previous paradigm, thus in a different mindset. It takes a long time to check and reinterpret or reject the accepted knowledge of the previous paradigm; and we will not even have a chance to do this if the new knowledge is not accepted. According to Kuhn new knowledge and new paradigms are accepted if they are convincing and if they promise better results. (cf. Section 2.1) Of course, it helps a lot if the scientists are unsatisfied with the old knowledge; they may accept the new knowledge because it is not unsatisfactory. Copernicus' conception did not provide, in the beginning, better results than the old Ptolemy-conception but, as they were already dissatisfied with Ptolemy, scientists gave a chance to the new conception.

Lakatos (1978) tries to unite the strengths of Popper's and Kuhn's conceptions. He rejects the sharp falsification (he also calls it dogmatic or naïve), saying that the whole new knowledge cannot (or can very rarely) be refuted by a single experiment or other piece of evidence but gradually enough falsifying evidence can be accumulated. Lakatos calls this a sophisticated falsification, which becomes his *"methodology of scientific research programmes"*. Lakatos also suggests making judgments about new knowledge considering the appropriateness of used methods/tools in the context of the history of science.

Lakatos and his friend, Feyerabend, agreed what to accept from Popper and Kuhn but they had exactly opposite opinions about methods. Feyerabend argues that anything should be allowed which leads to results; this is his famous principle that *"Anything goes!"* – which is why Lakatos called him an anarchist, and Feyerabend (1993, p. 12) accepted this title:

"Professional anarchists oppose any kind of restriction and they demand that the individual be permitted to develop freely, unhampered by laws, duties or obligations."

By fusion of Popper's and Kuhn's conception we can get evolutionary epistemology or epistemological Darwinism. The bases can be seen in both Popper and Kuhn

but it was actually developed by Campbel (Munz, 1985, p. 213 ff). According to the conception of evolutionary epistemology the rival knowledge candidates (and thus paradigms) are on the battlefield until one wins; this process has a direction towards greater generalization and higher level of abstraction.

This last conception can be in harmony with conceptions of Lakatos and/or Kuhn but we are still missing one link in the chain: who and how accepts or rejects the new knowledge if both the positive and the negative verification are unacceptable? The answer begins to dawn in Feyerabend and it is the most clearly formulated by Polányi (1966, p. 72) in what he calls *"the principle of mutual control"*:

"It consists, in the present case, of the simple fact that scientists keep watch over each other. Each scientist is both subject to criticism by all others and encouraged by their appreciation of him… It is clear that only fellow scientists working in closely related fields are competent to exercise direct authority over each other; but their personal fields will form chains of overlapping neighborhoods extending over the entire range of science."

Thus, thanks to the transdisciplinarity, we can cover all the domains with overlapping problem domains (personal fields) and get a certain balance of disciplines. In evaluation of the work of a fellow scientist we use value judgments based on our background knowledge and intuition. This conception seems to be what is actually done in science, e.g. in a review of a scientific paper or on a PhD viva. This kind of verification may be called interpersonal verification; it is also consistent with Habermas' (Bohman, 2005) communicative or discursive rationality and the principle of inter-subjectivity.

This section clarified what principles (namely Polányi's principle of mutual control, which is inter-subjective) are accepted for the present thesis as means of validation of new knowledge. To get more specifically an account on accepted and used methods,[1] these principles should be considered together with the explanations on the

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[1] *The term methodology can be correctly used in two different ways (Checkland, 1999a, A32): 1) it is a meta-method or a method about methods; 2) it is a discipline about methods. The second meaning is appropriate here.*

particular models from Sections 2.3 and 2.4 regarding the input from reality; some of these overlap with the methods of inference, namely the thought experiments and the discussions.

The following section is concerned with the methods (sometimes only tools, i.e. if used only once) of getting to results. Many of the traditional rules were refuted by philosophers of science for the validation-part and this is even more significant for the part of getting to the results – creativity.

2.6. On Creativity

> *"If you do what you've always done, you'll get what you've always gotten."*
>
> *Anthony Robbins[1]*

In the previous section the methods of validation of new knowledge were examined in general terms of criteria; i.e. what is required from the validation to consider it valid. Some methods/tools were also examined in particular for both getting input from reality and making inferences. This section is focused on the phase of scientific inquiry of getting to new knowledge; the methods/devices are examined from this aspect, considering also under which conditions they can be accepted. For induction, it was already shown that it is not legitimate as means of validation of new knowledge but that it can be a useful way of getting to results if we embrace subjectivity and intuition; in this section a special kind of induction is also introduced as it was used in the present investigation.

The section is called creativity as getting to new results always involves new ways of getting to results, and this is creativity. If a result can be achieved by means of following a recipe creativity is not needed but there will be no new result either. This would fall under task accomplishment, as it was explained in the introductory paragraphs of the present chapter. Achieving new results requires problem solving, and for problem solving we need creativity.

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[1] *http://www.nonstopenglish.com/reading/quotations/ and a couple of hundred other pages, though, sometimes a different author is assigned.*

Creativity can be regarded as a social phenomenon, i.e. that creativity happens in interaction between the creative individual and the socio-cultural context. To create something genuinely new that remains means that it has to be added to the culture of the group/organization/society and this means that it is not enough to get the new knowledge but also to get it accepted. This is why Csíkszentmihályi (1997, pp. 27-28) identified *"Creativity"* (with a capital C) in this sense as a system of three inter-related parts: 1) the knowledge shared within the domain, in which the creative achievement occurs; 2) the gatekeepers of the domain, who decide to let the new knowledge into the domain or not; and 3) the creative individual producing the novum. To make the distinction obvious Csíkszentmihályi calls the latter *"personal creativity"*. From the viewpoint of getting to a new result personal creativity is relevant; thus it is also relevant for this dissertation. Nevertheless, the knowledge shared within the domain has served as basis for achieving these results; this is acknowledged but not investigated in the present research.

The further explanation about the used methods begins, again, in negative narration, i.e. what is not used and why. A perfect rationale for this is given by Simon (1977, pp. 57-59); there is simply nothing to be added – this is the reason for such a long quotation:

"Operations research progressed from the talking to the action stage by finding tools with which to solve concrete managerial problems. Among the tools, some of them relatively new, some of them already known to statisticians, mathematicians or economists were linear programing, dynamic programing, integer programing, game theory, Bayesian decision theory, queuing theory, and probability theory… Whatever the specific mathematical tool, the general recipe for using it in management decision making is something like this: (1) Construct a mathematical model that satisfies the conditions of the tool to be used and which, at the same time, mirrors the important factors in the management situation to be analyzed. For success, the basic structure of the tool must fit the basic structure of the problem, although compromise and approximation is often necessary in order to fit them to each other. (2) Define a criterion function, a measure to be used for comparing the relative merits of various possible courses of action. (3) Obtain empirical estimates of the numerical parame-

ters in the model that specify the particular, concrete situation to which it is to be applied. (4) Carry through the mathematical calculations required to find the course of action which, for the specified parameter values, maximizes the criterion function. With each of the tools are associated computational procedures for carrying out these calculations more or less efficiently… But certain conditions must be satisfied in order to apply this recipe to a class of decision problems. First, mathematical variables must be defined to represent the important aspects of the situations. In particular, a quantitative criterion function must be defined. If the problem area is so hopelessly qualitative that it cannot be described even approximately in terms of such variables, the approach fails. Second, parameters of the model's structure have to be estimated before the model can be applied in a particular situation. Hence, there must exist ways of making actual numerical estimates of these parameters – estimates of sufficient accuracy for the practical task at hand. Third, the specification of the model must fit the mathematical tools to be used. If certain kinds of nonlinearities are absolutely crucial to an accurate description of the situation, linear programing simply won't work – it is a tool that is limited to mathematical systems that are, in a certain sense, linear. Fourth, the problem must be small enough that the calculations can be carried out in reasonable time and at a reasonable cost, although, of course, the computer has enabled us to handle immensely larger problems than we were able to handle without it."

Apart from getting a very clear picture about why the listed hard methods cannot be used in the present investigation, it can also be seen that there are many things involved that are actually outside of the method itself, such as selection and estimation of the parameters, choosing the appropriate model, etc. This means that even if one uses these methods one cannot just follow a recipe – which is actually good news, it is still a problem solving. Simon himself did not quite believe this; he was, for most of his career, trying to build a General Problem Solver (GPS). This is not a novel idea; Descartes held similar intention (Pólya, 1957, p. 92):

"Descartes, René (1596-1650), great mathematician and philosopher, planned to give a universal method to solve problems but he left unfinished his Rules for the Direction of the Mind."

To find a universal method of problem solving of a GPS we should find what is the same in all problem solving, in all creative processes. What is actually the same in these is that the problem solver sees the things differently from the way they are usually seen, she/he questions some things that are usually taken for granted and finds easy answers to others that are usually questioned. (Baracskai, 1998) The problem solver, during the problem solving, thinks differently. Of course, there is no algorithm of doing things differently – thus a GPS considered impossible for the present research.

De Bono calls this non-algorithmic part of thinking, which is responsible for our achievement in seeing things differently, lateral thinking (de Bono, 1971) and sometimes parallel thinking (de Bono, 1994), to contrast it to vertical (or convergent) thinking. The conception of lateral thinking can be easily grasped through jokes, more precisely, through examining how good jokes work. (Baracskai, 1998, pp. 45-47) In good jokes there is a convergent/vertical way of thinking along which the joke teller takes us; this convergent line, the mainstream, would lead to the obvious conclusion. This is the essence of convergent thinking; there is a single outcome and the thinking converges towards it. Then, all the sudden, the joke teller jumps out from the convergent mainstream of thinking in a lateral direction. The elements considered are rearranging to form a new order, to make new sense when we get to the punch line. If there were to be no new order it would not be a joke, it would be something senseless. Nobody would laugh. Why we laugh is because we understand that there is another way of thinking according to which the punch line is perfectly logical. It makes sense – but we would not have thought of it.

This is the way of thinking needed to create something new. There are two important characteristics. Firstly, the lateral detour is a discontinuity (de Bono, 1971, p. 88):

"A discontinuity is a change which does not arise as part of the natural development of a situation. Thus, a sudden kink on a graph suggests that the basic situation has changed, that some new factor has come in. A discontinuity also implies that the new factor does not arise from within the situation but from outside. In its extreme sense, discontinuity implies that the factor is not connected at all with the situation

under consideration… The word discontinuity is often applied when a connection cannot be seen."

Secondly, the lateral thinking is logical but only with hindsight. While we swim in the mainstream, the lateral runway cannot be seen; once we arrived at the end of the runway and we look back, it can be seen as another mainstream (de Bono, 1973, p. 88):

"In hindsight every single insight solution must be obvious. And usually it is the very obviousness of the solution that makes it so infuriating."

Creativity is about seeing things differently, but not in any different way! Not anyone can have creative insight in any field. This has a lot to do with Csíkszentmihályi's (see the beginning of this section) shared knowledge within the domain. If the previous knowledge was not important, those, who are creative, could be creative in any field. This is, of course, not the case. Dali and Buñuel are certainly creative individuals, but we surely would not ask them for a creative innovation in the field of eye surgery.[1]

Nevertheless, the knowledge of the person in itself cannot account for creativity. The research showed that the whole personality of the person is involved in it. Gardner (1993) examined creativity from cognitive viewpoint and found numerous factors that may in themselves or in some combinations indicate creativity. For instance, a multicultural background seems to go along with creativity, and creative individuals usually also seek experiencing different cultural settings; it is not clear, however, if there is a causal relationship here. Even the list of the relevant factors would exceed the length of this section, so probably it is better to indicate only that the whole personality is involved. An important observation is that all Western education (e.g. de Bono, 1993) goes against creativity but this topic is also far too large to be considered here.

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[1] *It is an allusion to their film "An Andalusian Dog".*

Hadamard (1954) investigated how new results are born in the field of mathematics, which is usually thought of as completely logical. His investigation confirmed both of the previous characteristics, i.e. that a previous deep knowledge is essential and that the novelty is born in a flash of intuition. According to Hadamard, the first phase is the conscious hard work of trying to solve some problem, then follows a forgetting phase, which may mean a continuation of the work unconsciously, and then comes the sudden insight accompanied by a sense of certainty. This is followed by another conscious phase of putting on paper, proving (in mathematics!) the result.

As the creative jump cannot be seen ex ante only ex post, it is impossible to make any algorithm or method for it. The creativity is desperately anti-methodological in Feyerabend's (1993) sense. The *"anything goes"* in the stage of getting to the results is not only allowed but compulsory (Feyerabend, 1987, p. 281):

"... the events and results that constitute science have no common structure; there are no elements that occur in every scientific investigation but are missing elsewhere... Successful research does not obey general standards; it relies now on one trick, now on another, and the moves that advance it are not always known to the movers... scientists will get a feeling for the richness of the historical process they want to transform, they will be encouraged to leave behind childish things such as logical rules and epistemological principles and to start thinking in more complex ways – and this is all we can do because of the nature of the material. A «theory» of knowledge that intends to do more loses touch with reality."

In his various books de Bono describes this non-algorithmic, anti-methodological nature of creativity and, quite surprisingly, he gives a series of methods for lateral thinking: the "PO" (de Bono, 1973), the "Six Thinking Hats" (de Bono, 1990), the "Aims, Goals and Objectives" (AGO), the "Consider All Factors" (CAF), the "Other People's Views" (OPV), the "Alternatives, Possibilities and Choices" (APC), the "First Important Priorities" (FIP), the "Consequence and Sequel" (C&S), the "Plus, Minus and Interesting" (PMI). (de Bono, 1993, pp. 63-150). To explain this apparent contradiction a personal experience is quoted here; it illustrates how methods can also serve to get rid of methods, as we are so addicted to them:

> *When I started to read de Bono's books, I loved them very much. He has seen creativity so clearly, contrasting it with our usual thinking habits and our all education… and then he gives methods for it. I was disappointed. The same thing happened in all of his books. I started to think that I should only read the first part of each of his books. The understanding came from a quite different kind of reading.*
>
> *Coelho[1] went to the desert to find his guardian angel and he had a series of steps to perform. One of these is called the ritual that destroys rituals. The explanation is that magi become slaves of their own rituals, so, occasionally they have to get rid of them; for this purpose they created a special ritual to help them step out. When I read this, I had to return to de Bono's books – now I understood. He created methods to help stepping out of our rituals. Methods that destroy methods.*

Of course we always do something in our inquiry which can be, with hindsight, identified as a method. Actually, if Feyerabend's anti-methodological approach is accepted, methods should be exclusively identified with hindsight. Deciding about the method in advance would be a severe limitation to creativity. Most of the methods used in the present dissertation were already introduced, namely the ex-post, first-, second-, and third-hand, unstructured phenomenological observations in natural context, and the thought experiments. There is one more method that was promised to be described, which is a special version of induction. In its formulation substantial use was made of Feyerabend's (1993, p. 20 ff) conception of counter-induction, according to which we should develop hypotheses inconsistent with highly confirmed theories and well-established facts. The inductive method that was used was also identified with hindsight, and it was indeed a substantially personal experience.

> *What actually happened is that I have been observing my mentor Zoltán Baracskai, not only as any apprentice is observing her/his master, but also as a researcher of cognitive sciences observers her/his subject. Of*

[1] *Coelho, Paulo (1995) The Valkyries, Harper Collins, London.*

course, I was not at all aware of this for long time. But later, I have real-ized at once that I had learned much more about knowledge and knowl-edge increase by observing a (grand)master[1] than from all my readings, observations, and self-observations. (Grand)masters are rare, so they are obviously not representatives of the human knowledge in general. When I realized this, I thought that I had just invented a new method; I even coined a name for it, I wanted to call it "niche-induction". But later I was disappointed when I found out that many researchers have already been using it.

This describes the last method used in this dissertation. It will not actually appear explicitly because, as it was described, it was used unconsciously and, although it provided essential understanding of knowledge increase, it was not deliberate.

It seems that it is actually very common to use this kind of induction for getting to new results: most of the results of psychology were achieved starting from examination of psychiatric patients, Gardner (1993, 1995, 1997) often examined extraordinary people, Csíkszentmihályi (1997) surveyed 91 extremely creative people, 12 of them Nobel laureates (two of them twice), and so forth ad infinitum. Pólya (1957, pp. 192-193) gives an account about this kind of induction:

"Extreme cases are particularly instructive. If a general statement is supposed to apply to all mammals it must apply even to such an unusual mammal as the whale… extreme cases are apt to be overlooked by the inventors of generalizations. If, how-ever, we find that the general statement is verified even in the extreme case, the in-ductive evidence derived from this verification will be strong, just because the pros-pect of refutation was strong."

So, not only was the 'new' method identified with hindsight, but it was not new at all. Still, it does not seem to have a name, so the coined one might still be appropri-ate. The creativity as introduced in the present section involves also creation of new methods. It was done so for the present research but then it was recognized to be al-

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[1] *(Grand)master is the highest level of knowledge as it will be introduced in Section 4.1.8.*

ready in use. The fact that it was not recognised earlier is not resulting from arrogance towards the existing literature; rather the reason seems to be that it was not previously identified as a particular model.

If the "anything goes" approach as means of getting to new results is a valid one, there is a connected issue that must be discussed: the freedom of the scientist.

2.7. On Freedom of the Scientist

> *"Each one of us has it in him to be a free spirit, just as every rose bud has in it a rose."*
>
> *Rudolf Steiner[1]*

The last element of the mental framework that was adopted in this research is the conception of freedom. It is relevant to multiple aspects of the dissertation and hence it is important to tackle this conception. Choosing a paradigm or choosing to create one involves freedom. Choosing methods or choosing to create new ones involves freedom. Seeing things differently, which proved essential for getting to new results, involves freedom. Freedom is necessary for both choice and creativity.

The present section is focused on the freedom of scientist, only getting into the conception of freedom in general to the depth that is necessary for the discussion. Apart from underlying the "anything goes" conception there are two topics examined, which are interrelated and also related to the conception of "anything goes": symbols and metaphors.

Freedom is the opposite of slavery. Of course, one may argue that there is no slavery in the modern world but there are other views as well; e.g. Marcuse ([1964](#), pp. 9-10) suggests taking our choices under closer examination:

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[1] *Steiner, Rudolf (1918/1964) The Philosophy of Freedom: The Basis for a Modern World Conception (7ᵗʰ edition), Rudolf Steiner Press, London. Online version: http://www.rsarchive.org/Books/GA004/TPOF/ (accessed 07/12/2004).*

"The range of choice open to the individual is not the decisive factor in determining the degree of human freedom, but what can be chosen and what is chosen by the individual."

Therefore he asserts that ([ibid](#), p. 36):

"The slaves of developed industrial civilization are sublimated slaves, but they are slaves, for slavery is determined neither by obedience nor by hardness of labor but by the status of being a mere instrument, and the reduction of man to the state of a thing."

Freedom can be fully understood only if examined in relation to the complete personality. ([Fromm, 1942](#), p. viii) Fromm ([ibid](#), p. 26) distinguishes two kinds of freedom: the negative, or *"freedom from"* and the positive or *"freedom to"*. Using this distinction the previous assertion becomes clearer ([ibid](#), ix): We are free from the bonds of the pre-individualistic society; but we are also left without the safety it guaranteed; we are left in isolation. There are two answers for this situation; either we seek new dependences and submissions or we advance to realization of positive freedom based on uniqueness and individuality. The answer is provided by Szondi's ([1954](#)) fate-analysis.

According to Szondi we have several possible fates for ourselves. These are determined by our genome and instincts (ontogenetic and philogenetic heritage) on one hand and by socio-cultural environment we are in throughout our lives on the other hand. Nobody can choose a fate that she/he has not seen and/or is not built into her/him. However, the (positively) free person can choose from the available ones, while the others live a constraint-fate. The first are the *"self-strong"* people, the second the *"self-weak"* or *"fate-ill"* people. He claims that only people who can choose their destiny can be happy. This shows, from a different perspective, that freedom is necessary to make our own choices – arguably, it is even more true for creativity, which is also a choice, a choice to see things differently and so to create a new order. And who can be free? According to Szondi the answer lies in the kid's room. This means the difference between being brought up to obedience or to freedom. The kid's room is not necessarily a separate room but a place where the child can realize

herself/himself. The famous Hungarian architect Imre Makovecz said in an interview that only those apprentices may become masters, who could look up to their fathers (dominant parent) – instead of fearing them. If one was trained for obedience it is difficult, to make one free (Marcuse, 1964, p. 44):

"... it must first enable its slaves to learn and see and think before they know what is going on and what they themselves can do to change it. And, to the degree to which the slaves have been preconditioned to exist as slaves and be content in that role, their liberation necessarily appears to come from without and from above. They must be «forced to be free», to «see objects as they are, and sometimes as they ought to appear», they must be shown the «good road» they are in search of."

To realize the "anything goes" as means of getting to results, we need both types of freedom. Negative freedom means that it is allowed by authorities and the positive freedom means that the scientist can do it (Fromm, 1942, p. 208):

"We are proud that we are not subject to any external authority, that we are free to express our thoughts and feelings... The right to express our thoughts, however, means something only if we are able to have thoughts of our own: freedom from external authority is a lasting gain only if the inner psychological conditions are such that we are able to establish our own individuality."

Geiger (1971, p. xxi), a former apprentice of Maslow, quotes a letter of his master in his introduction to Maslow's book:

"I live so much in my private world of Platonic essences, having all sorts of conversations with Plato & Socrates and trying to convince Spinoza and Bergson of things, & getting mad at Locke and Hobbs, that I only appear to others to be living in the world. I've had so much trouble... because I seem to mimic being conscious & interpersonal, I even carry on conversations and look intellectual. But then there is absolute and complete amnesia – and then I'm in trouble with my family!"

And he concludes:

"No one can say that these dialogues were «unreal». They bore too many fruits."

But freedom has its price. And this price is high. Freedom always goes together with responsibility. If one is told what to do or how to make one's choices – one is not responsible. But if one is free to choose from existing solutions or to create a new one then one is responsible for one's choices and creations. The freedom of the scientist, the anarchistic science can be understood in two different ways: One is *"a demand for acceptance without examination"* – this is rejected with no further explanation, considering it trivial. The other is *"a demand for an open exchange that seeks understanding without being tied to specific rules"* – this is the conception adopted here, with all its consequences (Feyerabend, 1987, p. 284):

"... an absence of «objective» standards does not mean less work; it means that scientists have to check all ingredients of their trade and not only those which philosophers and establishment scientists regard as characteristically scientific. Scientists can thus no longer say: we already have the correct methods and standards of research – all we need to do is to apply them. For according to the view of science that was defended by Mach, Boltzmann, Einstein and Bohr, and which I restated in AM,[1] scientists are not only responsible for the correct application of standards they have imported from elsewhere, they are responsible for the standards themselves."

This conception is the reason for the present chapter being this long and detailed.

One area in which the freedom of scientist plays an important, and usually not recognized, role is the area terminology, i.e. the definitions. The positivistic expectation for a scientific research is to use well-defined terms, i.e. sharp definitions in which one and only one meaning can be attached to each term. In his late work Wittgenstein (1953) examined the nature of meaning and thus definitions. He realized that there are no well-defined words in natural human languages; sharp definitions only exist if they are artificially created. According to Hársing (1999, pp. 40-45), although there are several types of definitions, all of them can be reduced to the Aristotelian or classic definition, which works the following way: We have to find a more general (and already defined) term, containing all the instances of what we are about to define; this is the *"genus proximus"*. Then we have to find a feature which distin-

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[1] *The acronym reads "Against Method" which is another book of the author.*

guishes the term that is about to be defined from everything else contained in genus proximus; so all the instances contained in the term have that feature and nothing else (at least in the genus proximus) does. This feature is called the *"differentia specifica"*. E.g. the definition of man can be 'man is a reasonable creature'; if we know what creature is, we know what it means to be reasonable, and there are no other creatures that are reasonable – in this case we have a proper definition. To be honest, the meaning does not work this way. This is why Polányi (Polányi-Prosch, 1977, p. 3) said:

"... the achievement of meaning cannot properly be divorced from intellectual freedom."

Wittgenstein (ibid) has shown through numerous examples that we cannot know the differentia specifica. If we want, for instance, to define what 'game' is, we should find at least a single feature, or a combination of features that is common in all games. Instead we have a huge number of features, and most of the games have most of these features – but there is nothing to distinguish games. As we cannot have definition we will also have no genus proximus, which should have been previously defined.

If we cannot have sharp definitions, probably it does not make sense to pretend that we do. The environment is changing too fast, so we cannot wait until our concepts become artificially and precisely defined. For business people it does not seem to matter that they cannot define e-business. We can try to substitute 'business' for genus proximus and 'e-' for differentia specifica, or the other way around, neither is going to work. Still, e-business is a powerful concept with a lot of research concentrated around it. Should all of these be abandoned until we find a proper sharp definition? No. What can we do? We can freely define e-business for the use of a particular research, temporarily. We may also use our freedom to leave e-business, as it is, a metaphor. We can search for the meaning of it during the ongoing research (Lyotard, 1984, p. 81):

"A postmodern artist or writer is in the position of a philosopher: the text he writes, the work he produces are not in principle governed by preestablished rules,

and they cannot be judged according to a determining judgement, by applying famil-iar categories to the text or to the work. Those rules and categories are what the work of art itself is looking for. The artist and the writer, then, are working without rules in order to formulate the rules of what will have been done… Post modern would have to be understood according to the paradox of the future (post) anterior (modo)."

Likewise, the postmodern scientist may use metaphors to build thought models. It is clear that we can express many things with metaphors, but the question can be turned around: Can we express without metaphors what we can with them? The crea-tive writers, artists, and most of the philosophers and scientist will answer with sound no. (Grey, 2000) Metaphors have emotional, aesthetic, etc. content, beside their cog-nitive content, but not only these are inexpressible without metaphors but the cogni-tive content too if we try to express something new. The most difficult thing to un-derstand is that novelties are not only inexpressible without metaphors but, some-times, the metaphors lead us to novelties. Grey calls this metaphorical insight. Eve-rybody knows Newton's story with the apple. If it was only the *apple* dropping to Newton's head he would never invent the law of gravity. To make this happen, the *metaphor of the apple* needed to drop on his head – and then it does not even matter if the real apple was also there or not.

In scientific research we often do not use 'ordinary' language but another system of signs. What is true for the definitions of terms in human language is also true for these other systems of signs. In mathematics we have a kind of language with all of its signs well-defined. However, not all the signs are well-defined. In the world of signs the symbols correspond to the metaphors of spoken language. And how the me-taphors advanced the meaning the symbols can help us achieve the same (Boulding, 1985, p. 154):

"A sign is a communication that has some one-to-one relationship with what it communicates and the behavior that it induces. Road signs are good example. When we come to a sign that says «stop», we stop, and then usually go again. Even here, a sign that says «drive carefully» will produce somewhat different behavior in different people. On a larger scale, in religion, politics, and the arts, symbols refer not so

much to something specific as to a general meaning of the total system. The search for meaning is a significant part of art, literature, and religion. Without meaning, indeed, the communications… are not significant. The meaning of meaning, however, is elusive. It is the Holy Grail of philosophy – always sought but never quite found. The power of symbols is one of the most puzzling things in human history."

My interest in the yin-yang symbol provided powerful stimulus to create a symbol which informed the present research, namely, the central part[1] of the figure in Appendix 2. This figure displays a 3-part version of the yin-yang symbol – the three component models – with a fourth model emerging in the center. There were also mathematical symbols adopted to provide a comprehensive and short description about knowledge as a system. Apart from being used as signs which make the description more compact, the inherent features of the symbols were also beneficial; e.g. by applying these mathematical symbols it was straightforward to see that if there is a function which is time-dependent, then derivation by time would make sense.

The scientist, as presented here, needs freedom to work in the paradigm that was outlined throughout this chapter. She/he needs freedom to use any starting point, any method she/he feels fitting to get to her/his results. She/he also needs freedom to use metaphors and symbols to express her/his novel ideas, and, sometimes, also to get to these novelties. This need for freedom is argued by many philosophers and scientists, from Polányi to Boulding, and probably the most forcefully by Feyerabend and some postmodern philosophers, such as Lyotard. Freedom was the last missing link in the chain introducing the mental framework – which was the role of this chapter. One more section remains of it to introduce the process of scientific problem solving as it was pursued in the present investigation.

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[1] *The central part contains the four models.*

2.8. The Process of Scientific Problem Solving

> *"I have had my solutions for a long time but I do not yet know how I am to arrive at them."*
>
> *Gauss[1]*

After the lengthy discussion of scientific inquiry in general through seven subsequent sections, the aim of this section is to describe the process of investigation of this thesis. As it can be expected according to the previous seven sections it was not devised as an ex ante plan but was recorded as an ex post recollection. The description evolves as a result in the third phase of a successive approximation, starting from the reductionist approach (cf. Section 3.2) to problem solving process, gradually abandoning presumptions considered to be unrealistic.

According to the approach of analysis-synthesis, the scientific problem domain is first divided into component problems[2] and then the component problems are further examined (analysis). Once the component problems are solved, the solution of the whole evolves from putting together the component solutions according to the relations recognized between the component problems (synthesis). This is necessary and wrong. It is necessary as our knowledge is insufficient to examine the whole problem space and it is wrong as it leads to the fault called vulgar cybernetics by Baracskai,[3] namely we want to create the whole from components, as a mere set of them.

To understand the inappropriateness of this approach – at least to this investigation – the underlying assumptions and implications of it are examined here (cf. pp. 33-35):

(1) The relations between the component problems can be known – before the problem is solved.

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[1] *Quoted by Polányi (1962a, p. 131).*

[2] *The component problems are often called «research questions»; however, the term used here is much more appropriate. A question needs answer while a problem needs solution; and the term «component problems» suggests that they are meaningful wholes.*

[3] *Baracskai used the term "vulgar cybernetics" during the meetings of the Apprenticeship School which he led. It refers to the inappropriateness of considering wholes as sum of parts. As he argues, wholes are not sums of the parts, they are not even something more (i.e. the sum of the parts plus something else), they are something else. (Cf. Section 3.2)*

(2) The original problem can be created from the component problems using the relations between them.

(3) The relations between the component solutions (solutions of the component problems) are the same as between the component problems.

(4) The relations are constant (they do not change) during the process of the solution of the component problems and while the solution is considered to be valid.

(5) Presuming that (1)-(4) are true; a conclusion can be drawn that the solution of the problem can be generated from the component solutions based on the relations between the component problems. Using the markings of Figure 5: Problem P is divided into component problems $P_A \ldots P_E$, their solutions $S_A \ldots S_E$ produce the solution S.
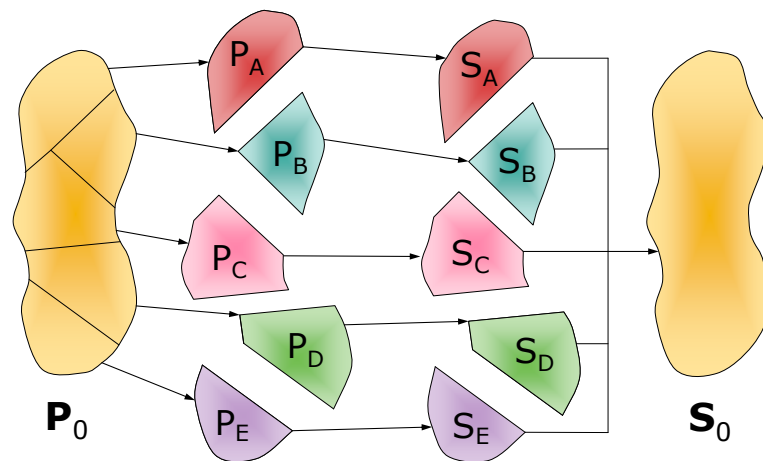
Figure 5: The solution evolves from the component solutions.

The first assumption indicates a deeper conception; i.e. it is only valid if we believe that the relations of the component problems that we have revealed present some kind of ultimate truth, like finding the philosophers' stone. However, according to Section 2.4 the only thing that we can state about the relations between the components is that we see them this way here and now. How we see something depends – amongst others – on our knowledge. While solving the component problems our knowledge increases. Nothing justifies the presumption that we will see the relations between the components the same way with our increased knowledge.

Looking for a more appropriate approach, we can try to follow Pólya's (1957) train of thought: Break the problem domain into components according to a chosen aspect; solve the component problems; but do not try to generate the solution from the component solutions.[1] Our knowledge increased while solving the component problems; review the original problem with the increased knowledge – it is the first time that we can see it; i.e. now we see something different from the problem domain which we have seen at the beginning; and it is also different from the final definition of the problem. Solve the problem, if we can. If we cannot, break it into component problem using some other aspect. Due to the knowledge increase, the aspects we see are also different; there may be new ones, changed ones and some of the previous ones may also disappear. Repeat these steps until we can solve the problem as a whole. If we cannot solve any of the component problems, apply the same steps starting from another aspect.

Using the markings of Figure 6 (showing only one step of the iteration): Problem domain P_0 is seen with existing knowledge K_0. Solving component problems $P_A... P_E$ (component solutions $S_A... S_E$) our knowledge increases to K_1, which makes us see P_1. Its solution is S_1.

In scientific problem solving the scientific result is to be achieved, it is not fundamental which problem is solved, but to create a solution, a novum. In this respect the scientist is unique; as Kuhn (1962, p. 164) observed:

"Unlike the engineer and many doctors, and most theologians, the scientist need not choose problems because they urgently need solution and without regard for the tools available to solve them."

---

[1] *In actual fact Pólya (1957, pp. 50-51 and p. 77) suggests use of auxiliary problems; this is a more general category of which component problems form only one subset, the so called specialized problems. There are other auxiliary problems, like the generalized or the related problems; but any problem can be considered that is not solved for its own sake but to advance our original problem solving. The use of the original concept would lead to a more general model but this discussion will take a different direction in the third phase of the section, so we can stick to the narrower concept of component problems.*
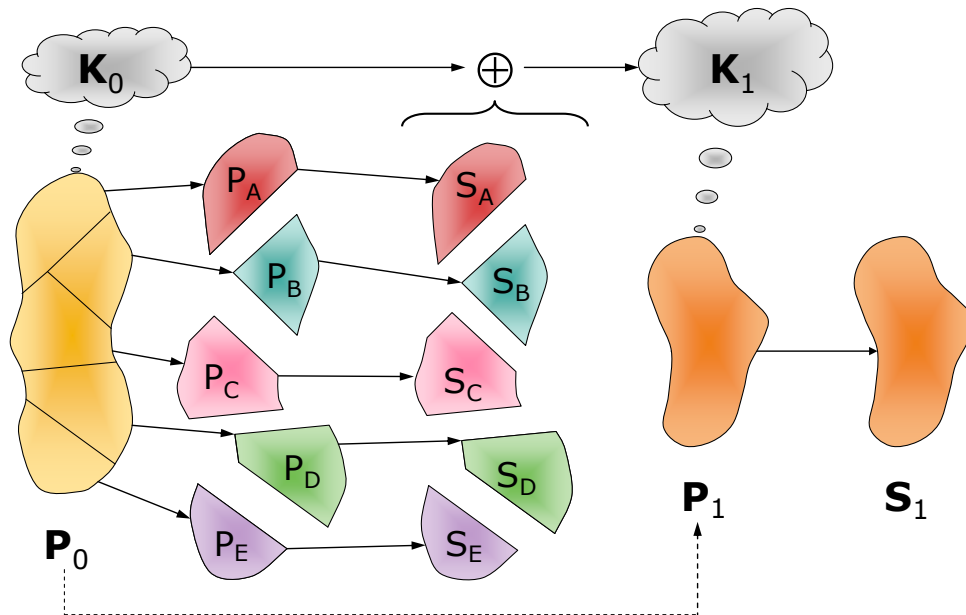
Figure 6: Examining the problem with the increased knowledge.

Einstein (1956, p. 30) argues similarly:

"… science, if it is to flourish, must have no practical end in view."

The scientist can use a particularly exciting problem or one that she/he seems to be particularly able to solve, or that she/he finds interesting for whatever reason. According to Kuhn (ibid) this also accounts for the more rapid rate of problem solving in natural than in social sciences:

"The latter often tend, as the former almost never do, to defend their choice of a research problem – e.g., the effects of racial discrimination or the causes of the business cycle – chiefly in terms of the social importance of achieving a solution."

This common fault of social sciences is not committed in the present research – with my mentor I chose the problem domain, which interested me the most and in which I already had substantial knowledge.

To make use of this conception the previous train of thought should be reversed; the first step is the same, the problem domain is decomposed into component problems. We then start to solve the component problems; we can solve some of them, others will be divided further and there will be some to remain unsolved. That is not necessarily because we cannot solve them, but because they do not belong into the

main stream of thought, which is not yet formulated, but which nevertheless already controls our investigation. (Figure 7)
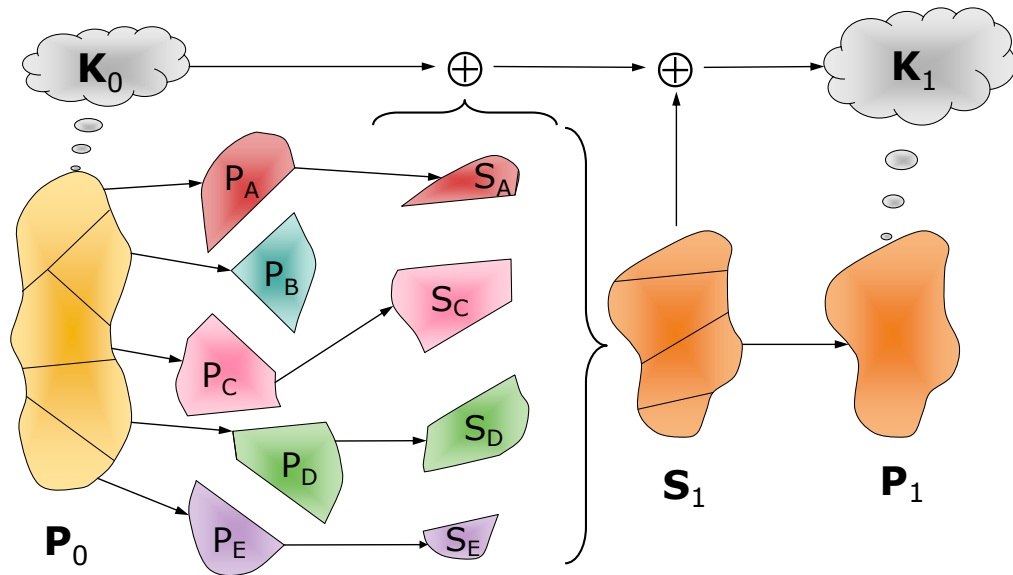
Figure 7: The solution determines the problem.

The problem-solving process of this investigation is introduced as an illustrative example here, though there is more to it – this should be considered as the brief methodological framework of the dissertation. As it can be expected after the previous seven sections, it was not developed as a plan for the research ex ante but it was recorded ex post.

During the preliminary consultations[1] the knowledge increase evolved into the problem domain; and as result of the discussion a few initial component problems were identified within it:

- it is not known how to model the process of knowledge increase;

- it is not known how to model the fitness of the increased knowledge;

- it is not known which factors influence the absorption of the new knowledge;

- it is not known how to model the effect of these factors on the knowledge absorption;

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[1] *I.e. between my mentor and myself.*

- it is not known how to choose the benchmark for the best support of the fitness of the increased knowledge.

Some of the component problems were solved; e.g. the model of knowledge increase is developed. Some of them did not have fitness strong enough in this investigation, and they withered; namely the fitness of the increased knowledge and the benchmark. Some of them were further divided and restructured, such as the parameters influencing the knowledge absorption.

While solving the component problems the picture of the problem becomes more and more clear. Some of the component solutions form a new solution. Of course, not all component solutions will be part of the new solution. This happened in this thesis as well. When the new solution is formed (as matter of fact, somewhat earlier) the problem can be formulated about which solution is achieved.

This last assertion is not only experienced during this investigation but is also in complete accordance with Pólya's (1957, p. 158) explanation:

"As we progress toward our final goal we see more and more of it, and when we see it better we judge that we are nearer to it. As our examination of the problem advances, we foresee more and more clearly what should be done for the solution and how it should be done… We do not foresee such things with certainty, only with a certain degree of plausibility. We shall attain complete certainty when we have obtained the complete solution, but before obtaining certainty we must often be satisfied with a more or less plausible guess."

When presenting a scientific result the clearly formulated problem is used as starting point, which is attained only near to the end of the investigation. Naturally a well-structured presentation shows nothing about the ill-structured process, which led to the result of the investigation. The scientific result makes a new order, which is not necessarily better than the former one, only different. The well-structured report must explain this new order, which provides the structure and the logical flow of the discussion; but it has little to say about how the novelty was born in the mind of the scientist, except occasionally as a kind of recollection; necessarily subjective and un-

reliable just as the memory of the researcher. Some of these are also included in this dissertation, not as proofs, rather as anecdotal illustrations to give an impression about the underlying process.

2.9. Chapter Summary

The present chapter introduced the mental framework which was adopted in this investigation and the process of scientific problem solving as it happened. It discussed the adopted paradigm, the methods that are rejected and those that are accepted; grouping them around two phases of the scientific inquiry, namely getting to the results and evaluating them; and finally the freedom of scientist in considering it necessary for achieving and presenting the novum.

The adopted paradigm for the dissertation is a postmodern one. The positivistic paradigm is rejected. However, as the adopted "anything goes" conception indicates, positivism is only rejected for the present research, not altogether. If anything goes, positivism may also be accepted at some stage. Perhaps in some other research. Perhaps for someone else. Positivism should be denied the exclusivity – but no other paradigm should get it either. The adopted paradigm is an open one. Anything goes.

Several methods were adopted for the research, consciously or, more often, unconsciously, namely the ex-post, first-, second-, and third-hand, unstructured phenomenological observations in natural context, and the thought experiments. A new method was also developed and named niche-induction, just to find out that it was already in use by numerous researchers – although, there was no name for it. Apart from the specific methods introduced, on conceptual level, Feyerabend's anti-methodological approach is adopted, which culminates in the freedom of scientist as a necessary ingredient of scientific research as conducted here.

Finally the process of scientific problem solving is introduced, as it was used in the present investigation, not devised as an ex ante plan but recognized ex post.

3. The Problem Domain

> *"God, give me strength to change what I can change, patience for what I cannot change and wisdom to distinguish the one from the other."[1]*

The purpose of this chapter is to give an overview of specific parts of background knowledge of the neighbours around the problem domain (Figure 4, covering the second-top layer of Figure 3). The rationale for this choice is that these parts are used in one way or another in this dissertation; but that do not belong to the more specific discussion of knowledge and knowledge increase – which will be dealt with in the next chapter. This corresponds to the second cycle of the spiral of discussion. (See Figure 3 in the Introduction and also Appendix 2) Due to the transdisciplinarity of the problem domain (Section 2.1) this means taking the relevant aspects of various neighbour disciplines into account.

The first section discusses a part of the background knowledge of the problem domain that does not manifest itself directly in the process of modelling or in the resulting model but which is very important as a basis of the thinking during the modelling: The rationality of the person taking the decision whether to acquire the new knowledge or not, which is described by one of the resulting models of the dissertation (MLW), is important in the framework for this decision.

There are other parts of background knowledge in the problem domain that are directly applied at particular stages of modelling. These areas are introduced in the following sections without aiming to discuss the disciplines used in their totality; only those part are discussed which are relevant as a viewpoint, a method, an assumption, a belief, etc., and so which are directly borrowed from them for the sake of this investigation. Other parts of these neighbour disciplines are discussed only to extent which is necessary to distinguish the 'borrowed tools' from the other ones used in that discipline.

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[1] *This quotation is attributed to variety of sources; probably the most frequent ones are Heracleitus, Reinhold Niebuhr, and the Dakota Indians.*

3.1. Rationalities for Decision Taking[1]

"... sometimes the only possible rational behavior is irrationality."

László Mérő[2]

In one of the models developed for this dissertation (MLW) the person decides whether to acquire the new knowledge; the process of this decision is described in detail in Chapter 6.2. A decision always happens in a framework of rationality, and this section introduces this framework. However, although the rationality will not appear explicitly in the later model, the picture, which is maintained about the rationality, certainly influenced the elaboration of the model – and in that way it is tacitly included. Thus it is correct to find a place to present this picture of rationality explicitly.

First a description of the decision situation is introduced, then, using the notions from this description, three types of rationalities are introduced: the total, the bounded, and the intuitive rationality. The first one is rejected, while the other two are integrated into a single framework for the MLW. The functioning of the framework is shown through the reasoning of the person coming to a decision.

Decision can be presented as evaluation of decision alternatives according to decision aspects. The aspects of the decision are the attributes of decision alternatives. To determine the position of a decision alternative regarding an attribute values are used. On Figure 8 the attributes are indicated with different shapes and values are indicated with different colours. The values are ordered from the worst to the best one, the worst value is black, and the best one is white. Different attributes may have a different number of values.[3]

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[1] *There is a result presented in this section which falls outside the main stream of the present inquiry; it was published as a conference paper. (Dörfler, 2005)*

[2] *Mérő (1998, p. 61)*

[3] *Note that vertically there is no relationship between the values; they are only ordered from the worst to the best for each attribute.*
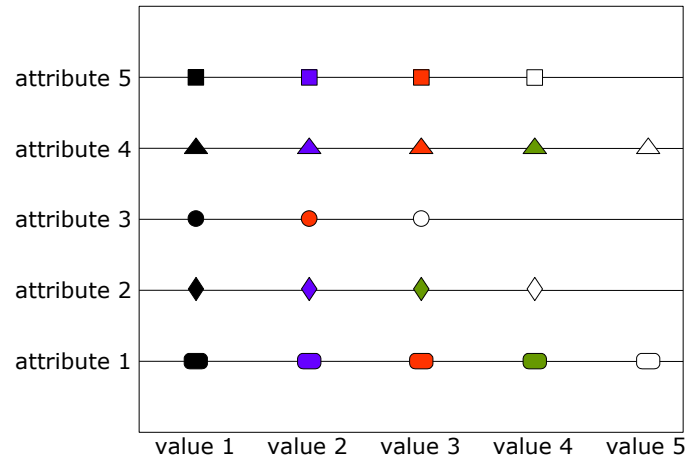
Figure 8: Decision alternatives described.

In this description the values of attributes are discrete, i.e. they are symbols not numbers. If an attribute is numeric, the range of the attribute should be continuous, however, this kind of description is easier to handle than the continuous one, and it introduces no limitation.[1] One value of each attribute is assigned to each decision alternative; the set of these values forms the features of the solution.

Total rationality leads to optimal solution (finding the best decision alternative). The decision taker searches for all decision alternatives and compares their features to each other. According to followers of total rationality this comparison considers each and every aspect, i.e. attributes of the solution. This is the underlying concept of the *homo economicus*. (Sen, 2002, p. 19 ff) Of course, in reality, this is impossible for a number of reasons, e.g. there are too many solutions to find all of them; identification of some of the attributes would require knowledge that is not yet acquired; if all the decision alternatives and attributes have been identified there is still the task to gather data about each and every alternative, considering each and every attribute; and there is also a time-limit. March and Simon (1993, p. 157 ff) examined numerous limitations of rationality; the above-mentioned limitations on the number of attributes and alternatives are direct consequences of cognitive and organizational limits (and the time-limit that is already mentioned). In this dissertation the total rationality

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[1] *I.e. there is no limitation regarding the rationality of the decision taker. If we relate the description to the knowledge of the decision taker, the choice between discrete and continuous domains, that is, between symbols and numbers, would make a major difference: e.g. the difference between quantitative and qualitative decision support systems.*

is not investigated, it is only used as a reference point to the other forms of rationality. What is important here is that in total rationality there is a search, which results in optimal solution.

Simon (1976) discovered and invented the concept of bounded rationality. Naturally, people did not start using the new sort of rationality once it has been discovered, they have always used it. However, it was a significant explanation of the human behaviour of the decision taker. (Foss, 2002) Simon gives two choices to the decision taker:

The first is to take their decision according to the total rationality described in the previous paragraph, though the searching space – the number of decision alternatives and the aspects considered – and the time-span of comparison get limited. Baracskai (1997) calls this the impermissible oversimplification of reality. It is not Simon who simplifies the world impermissibly but the decision taker adopting this framework of rationality. This kind of decision taker believes that the world and they themselves in it operate according to the total rationality. They do not take cognizance of limitations, believing that they really do search for the best solution.

The other possibility for the decision taker is to define his expectations and aspiration levels and to start the search afterwards. There is no complete agreement about how these terms should be used, here they are used the following way: An expectation is one value of one attribute, a full set of expectations (one value or a value range of each attribute) forms an aspiration. Using the notions from Figure 8, for example, ■ + ▲ + ○ + ◆ + ⬤ is an aspiration. If the outcome of a decision is also described using an attribute (called the decision attribute) and its values (the grades of the outcome), each value of the decision attribute indicates an aspiration level that may correspond to different sets of expectations, i.e. several aspirations may belong to the same aspiration level. Thus we can say that the aspiration levels are determined by expectations and their relations. The highest aspiration level refers to acceptability (there is no sense in refining the aspiration levels beyond this point). Once the aspiration levels are defined, the solutions come one-by-one; the decision taker compares the features of a solution to her/his aspiration levels before proceeding to another solution, taking a series of decisions. Time plays an important role in this

kind of search: if no alternative is accepted for a long while (i.e. no alternative fits the highest aspiration level), the decision taker modifies her/his expectations and/or the relations among them.

Later Simon (Frantz, 2003) refined this model, adding, that the decision taker may reform her/his expectations along the way. In bounded rationality, the result of the search is the satisfactory solution which satisfies explicit expectations of the decision taker, i.e. the expectations that he was able to define in advance.

Oppositely to Simon's model Baracskai (2000) emphasises that the expectations are formed along the way. Hence, the decision taker starts to search, examines the decision alternatives one by one, without previously defined expectations. Seeing the alternatives she/he defines objections. This kind of search Baracskai calls browsing as it can be well observed in those surfing the internet. Similar to expectations, an objection is also a value of an attribute. When an expectation is defined, we refer to a value of an attribute saying something like «I want it to be at least ⬭», which means that a lower limit of acceptable values is defined. When we define an objection, a value of an attribute is referred similarly to «I don't like it to be ▲, I want something better», so the upper limit of unacceptable values is defined. It is obvious that once an objection is defined it is easy to transform it into an expectation; thus Baracskai says that objections are inverse expectations. Similarly to Simon, Baracskai also assigns important role to time: if, for a long while, the decision taker does not find a solution that she/he has no objection against, she/he modifies her/his objections and/or the relations among them. As Simon's decision taker has to give up some of her/his expectations when the time presses, Baracskai's decision taker has to give up some of her/his objections.

Similarly to Simon, Baracskai too smoothed his model, acknowledging that we actually always have some expectations at the beginning of the search. The rationality of Baracskai's decision taker can be called the intuitive rationality, accepting Simon's (1990, p. 200 ff) terminology. The result of the search in intuitive rationality is the objectionless solution.

The three mentioned rationalities can be presented on a picture by their solutions. (Figure 9) In the set of all solutions, there are subsets of satisfactory and objectionless solutions; these subsets have their intersection and there are also solutions within it; i.e. these are satisfactory and objectionless at the same time. One of the elements inside the intersection is the optimal solution.
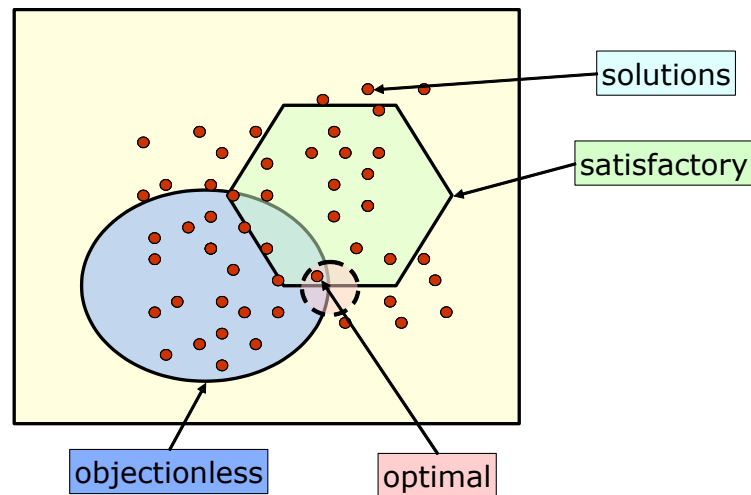
Figure 9: Optimal, satisfactory and objectionless solutions.

From this point onwards the total rationality will be abandoned, as it fulfilled its role as a reference point. Now the goal is to bring the two other rationalities into a single framework; this integrated rationality is assumed to be the rationality of the person in the MLW, as it seems to fit the reality better than the previous conceptions. For this, another model is needed, which has been also created by Simon (1977) in which he places the decisions along a continuum; on one end there are the programmed (or well-structured) decisions and on the other end the non-programmed (or ill-structured) ones. The two extremities (the black and the white) do not exist in reality, real decisions are in-between these two in the shades of grey.

Programmed decisions are those ones associated with bounded rationality and therefore with the satisfactory solution. Programmability in this situation means that all the expectations and the relations among them are exactly known. To program these decisions, we should also consider the expectations unchangeable.[1] As the other

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[1] *Or we need to develop a programmed meta-decision for modifying the expectations and/or the relations among them.*

extremity means to know nothing about the expectations and their relations, we can associate it with the domain of intuitive rationality and the objectionless solution; namely it is only impossible to programme anything, if none of the expectations is known. Therefore the rationality-models of Simon and Baracskai both are in the same dimension and both are non-existing extremities. If the reality was between these two, as Simon's second model suggested, then in reality the reasoning of the decision taker could be described as an *integrated rationality*, meaning that Simon's and Baracskai's model would be integrated. This integrated rationality could be considered to be characteristic of a decision taker (whether to acquire the new knowledge or not); therefore it is important to describe it explicitly, although, it will not appear explicitly in the Model of Learning Willingness (see later in this section). The steps of the decision process according to integrated rationality can be described as follows:

(1) She/he defines her/his explicit expectations and the relations among them before starting the search.

(2) While searching, the decision alternatives are coming one by one, seeing one she/he compares it to her/his existing aspirations and also makes her/his objections.

(3) Inverting the objections she/he defines new expectations and integrates the new expectations into her/his existing system of expectations. This is not a simple addition; integration of a new expectation invokes a process of complex interaction of expectations, during which the existing expectations and/or their relations may also alter (similarly to the incorporation of new knowledge as described in Section 6.1)

These steps are repeated for each decision alternative considered and the process ends when an alternative is accepted, consistent to descriptions of both Simon and Baracskai.

If we (re)draw the picture from Figure 9 regarding one moment from the previous process, one person and one decision situation, then the sets of satisfactory and objectionless solutions will not differ. Namely at that very moment, that very person, in

that very situation has some expectations and all her/his arisen objections can be inverted into expectations. The objections that have not yet arisen belong to the tacit domain or do not exist; in any case, they cannot be put into words. Thus for each moment the sets of the satisfactory and objectionless solutions are the same. Naturally if two different moments are regarded, then these sets may differ, however, that is not the same decision situation, thus it should not be put into the same picture. The picture is very useful to distinguish the two types of rationality, but as the decision taker is always somewhere in-between these two, the accepted alternative is satisfactory and objectionless in that very moment – i.e. when accepted.

The integration of the two approaches to the rationality of decision taking, the conception of integrated rationality, is an original contribution of this dissertation but it is not part of the result presented as it does not fall into the mainstream of the logical argument. Thus this new rationality does not appear explicitly in the result of the dissertation but is considered as a framework for the MLW, i.e. this is the supposed rationality of the person deciding to accept the new knowledge or not.

3.2. Systems

> *"But, after all, understanding big pictures, grasping the ways in which separate parts reinforce one another, is a thing at which our nose-to-the-ground, call-in-the-specialist! civilization is consistently rotten."*
>
> *David Gelernter[1]*

The systems-approach is one of the dominant pieces of knowledge background in this dissertation, and it is the first one discussed here that explicitly appears in the resulting models. It can be detected throughout Chapter 2 as general attribute of the whole investigation and it is also applied specifically to describe knowledge and knowledge increase in the modelling stage (Section 6.1 ff). This section aims to introduce the contemporary view of systems, not aiming to completeness, rather focusing on the aspects relevant for the present dissertation. Apart from the general de-

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[1] *Gelernter, David (1999) The Aesthetics of Computing, Orion Books, London, p. 8.*

scription the levels of complexity and processes in systemic view are introduced in particular; and systemists' tools/methods which are used in this dissertation are also described.

If we accept Bertalanffy's (1969, p. 55) definition that:

"A system can be defined as a set of elements standing in interrelations."

we can say that we investigate systems all the time in all the disciplines. So what is so special about systems? The system thinking, as we know it today, came into life in '50s as an institutionalized version of holistic thinking, i.e. as an opposition to reductionism. (Checkland, 1999a, p. A3) This means that if something is regarded as a system, it is acknowledged to have emergent properties that cannot be derived from the properties of its elements. As reductionism-atomism is still strong in positivism today (as introduced in Section 2.5) the opposing arguments are extensively discussed in systemist literature, and hence, these arguments are briefly presented here.

There are two variants of the holistic approach: according to the first, if we knew all the properties of all the elements and all their interrelations, the emergent properties could be derived (e.g. Minsky, 1988, pp. 26-27). The only trouble is that we do not know them. According to the second there are emergent properties of the whole that are essentially non-derivable from its parts and their interrelations; e.g. Polányi (1966, p. 36) suggests the example of language:

"... you cannot derive the grammar of a language from its vocabulary; a correct use of grammar does not account for good style…"

Either we accept the first (that we cannot know all the properties of all the elements and their interrelations) or the second variant (that even if we knew all these we could not construct the whole from the elements), for now we must accept the existence of emergent properties, as we cannot handle all the elements with all their interrelations. To justify this opinion, an account is given here about the limitations. First, assume very simple elements, e.g. electrons and protons; how many of them can be handled together? Bertalanffy (1969, p. 5) quotes Szent-Györgyi:

"[When I joined the Institute for Advanced Study in Princeton] I did this in the hope that by rubbing elbows with those great atomic physicists and mathematicians I would learn something about living matters. But as soon as I revealed that in any living system there are more than two electrons, the physicists would not speak to me. With all their computers they could not say what the third electron might do. So that little electron knows something that all the wise men of Princeton don't, and this can only be something very simple."

The quotation is still relevant: the physicists still cannot solve the "three body problem", i.e. give motion equations[1] of three mutually interrelated bodies (László, 2001, p. 14). On the other hand, if there are only two but not so simple elements, we are stuck again (László, op. cit. p. 38):

"The friends or the lovers as individual partners do not have all the properties of their relationship."

The number of relations escalates incredibly with the increase of the number of elements (Bertalanffy, 1969, pp. 25-26):

"Consider, for a simple example, a directed graph of N points. Between each pair an arrow may exist or may not exist (two possibilities). There are therefore $2^{N(N-1)}$ different ways to connect N points. If N is only 5, there are over a million ways to connect the points. With N=20, the number of ways exceeds the estimated number of atoms in the universe."

It is of course possible that we want to handle a system of more than 20 elements, as well as more complex interrelations than the previous directed graph. So, even if we accept that it might be possible to derive the properties of the whole from the properties of its elements and their interrelations, we must use the conception of emergent properties of the whole as we cannot handle the complexity of the parts.

If we accept that all around us in the real world there are systems, we must recognize that they are essentially multileveled. The systems view of multileveled hierar-

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[1] *I.e. it cannot be done in a closed form; various approximations are possible.*

chies is very different from the reductionist approach to multileveled reality. The reductionist thinking initiated a quest for the ultimate building blocks of everything, thus it is also attributed as atomist.

Different disciplines accounted for the considerable success achieved in discovering the smallest elements of the systems they investigate: the elementary particles identified as building blocks of matter by physicists, the cells found to be the building blocks of living organisms by biologists, the genes supposed to be the building blocks of heredity, etc. The discovery of building blocks was always accompanied by great expectations, i.e. that we will get some final answers. And yet, it has never happened. Something always went terribly wrong. According to Fukuyama (2003, p. 73) the Human Genome Project was accomplished in June 2000,[1] the genetic code is broken; still, we are nowhere near being able to modify human DNA, we only have

"the transcript of a book written in a language that is only partially understood."

The physicists tried to divide the known particles of matter into smaller and smaller, aiming to arrive finally to the elementary particles. This is done by firing particles against each other. However, the presently-known smallest particles do not seem to be the final ones. In collisions of these particles no smaller particles are produced, only particles of the same sort; i.e. as if they are somehow transformed into each other. To Capra (1991) this suggests that there are probably no ultimate building blocks at all.

The hierarchical view of systems does not imply search for ultimate building blocks, rather, it gives a certain focus for our investigations; i.e. to consider three levels of system in any examination: the *"system"*, the *"sub-system"*[2] and the *"wider system"*. (Checkland, 1999a, pp. A23-A24) Thus the notion of holons is introduced,

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[1] *According to National Human Genome Research Institute (n.d.) it was completed in April 2003. See the same site and National Center for Biotechnology Information (n.d.) for further interesting information, including genetic graphs/maps.*

[2] *Checkland uses the notion of sub-system to refer to the holonic nature of the elements of the system. Henceforward, if not indicated otherwise, the term will indicate a subset of the elements of a system; for distinction it will be written as a single word: subsystem.*

i.e. entities that are elements of a whole on one level in hierarchy and wholes consti-
tuting of elements themselves on the other level. ([Checkland, 1999b](#), p. 82)[1]

So far it has been argued that the reductionist-atomist approach should be re-
jected, and the hierarchical nature of systems focused upon. To define a system we
need to define the elements, their relationships, the system boundary, the environ-
ment, the input and the output (relationships between the system and the environment
in terms of matter, information, etc. exchange). (Figure 10)

There are additional features that are applicable to some systems and not applica-
ble to other ones. These will be introduced through levels of systems defined accord-
ing to increasing complexity.
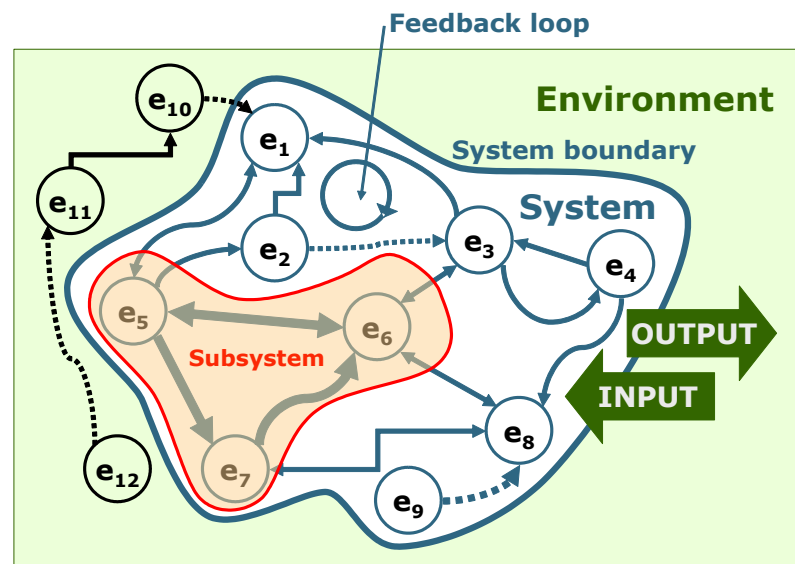
Source: Adapted from Flood and Jackson ([1991](#), p. 6)

Figure 10: General conception of system.

The discussion of system levels follows Boulding's ([1956](#)) most famous 9-level
model, also quoted by Bertalanffy ([1969](#), pp. 28-29) and Checkland ([1999b](#), p. 105),
but Boulding's ([1985](#), pp. 9-30) other 11-level model is also considered. Each system
level is identified using a metaphor:

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[1] *The term of "holon" was introduced by Koestler, Jacob used "integron" and Gerard used
"org" for the same concept. (see [Checkland, ibid](#))*

(1) **Scaffolding**: The simplest system type would mean elements in a fixed, constant relationship; neither the elements nor their relationship moves or changes in time. The impact of the environment is negligible. This is a static, closed, mechanical system. Mechanical constructions (like scaffolding or frameworks) or landscapes are the usual appearance; though, depending on the aim of the inquiry, we can regard sometimes the bones of a human head or factory layout to be scaffoldings.

(2) **Clockwork**: A system is one level more complex if its elements are still unchanging but their relative position in space changes. The interrelationships between the elements are now changing in a predetermined way, usually in cyclic manner. These are the dynamic closed systems, as the environmental impact is still neglected, although we know that clockwork is to be wound up. The simple machines (clockworks, motors, etc.) belong to this group; in humans the skeleton and in businesses an assembly line can sometimes be regarded as clockworks.

(3) **Thermostat**: Sometimes the relations between the elements or between the system and its environment form a 'circle', which is a negative or positive feedback loop. If the feedback is between the system and its environment, it is usually limited to a single input-output relation but, at least, the environmental impacts are not totally neglected anymore. These are the first open systems and they also involve the concept of information (transmission and interpretation). Cybernetic or negative feedback systems maintain equilibrium of a single quantity in a changing environment; this phenomenon is called homeostasis. Beside the thermostat all the sophisticated mechanical systems belong here, e.g. the computers; in human there are also numerous homeostatic subsystems, like the blood pressure, and in a business organization a salary could be considered here. The positive feedback systems usually do not last, because, as Forrester (1971) and Meadows (Meadows-Randers-Meadows, 2005) argued, there is always a natural limit to growth. From nature a pile of sand or a rabbit population are examples of positive feedback, and from human affairs the escalating love and quarrel can be considered. Great importance of these systems is that we have

(more or less) complete knowledge of a thermostat – and the same cannot be said about the systems of higher complexity.

(4) **Cell**: Living systems show a bunch of new features, although, there is no single feature that could distinguish the living from the non-living. These systems go beyond the simple homeostasis: they can adapt themselves to their environment by transforming themselves; e.g. the default value of the blood pressure changes in a person if she/he spends a long time on significantly higher or lower (according to sea level) spot then previously – but some gases show similar behaviour. This phenomenon is called self-maintenance (in flow of matter), and it often also includes some kind of self-repair. A living thing can reproduce itself (it is a kind of self-maintenance on population level) – but also can some crystals. Example from higher levels could be the metabolism of a human.

(5) **Plant**: Living systems, consisting of functionally organized elements forming mutually dependent parts (division of labour), are of a higher level of complexity although the boundary is unclear again. These systems demonstrate creodic nature, i.e. they can go through structural changes over time, as if following some plan; and if the plan is sometimes temporarily put aside, it is often resumed. The same final state can be achieved from different initial conditions and in different ways, which phenomenon is called equifinality by Bertalanffy (1969, p. 79). Systems of this complexity also have identity, i.e. the individual specimens are distinguishable. On higher levels of complexity, the creodic nature is e.g. building from an architect's plan; equifinality is e.g. the growth of a baby; and we can also recognize individual humans or human organizations.

(6) **Animal**: Shifting gradually from the previous level we arrive to systems of increased mobility. These system also show teleological behaviour, or as Bertalanffy (ibid) calls it, purposiveness, meaning that the behaviour seems to be determined by the goal. The communication, as we usually understand it, also appears at this level. These systems also seem to show self-awareness, though it is debatable when it appears as the communication

with animals is rather difficult; on the other hand learning ability of these systems is evident. It would be trivial to quote any examples from humans or human organizations.

(7) **Human**: Individual human beings display several features not (or barely) observable in animals. Beyond simple self-awareness we are self-conscious; we do not only have knowledge but we also know about our knowledge, we can perceive that we are perceiving (László, 2001, p. 92 ff), so we are blessed and cursed with meta-cognition.[1] Humans have symbolic language appropriate to handle abstractions as well as the concept of future and past. These also make possible to learn from others' experiences, so called second-hand learning or passed-on learning (de Bono, 1976, pp. 12-14), without going through the trial-and-error process of first-hand learning. Humans also take the purposiveness to a higher level of "true purposiveness" or "Aristotelian purposiveness" (Bertalanffy, 1981, p. 3) meaning that:

"... the future goal is anticipated in thought and determines actual behaviour."

Of course, humans can only be observed in their interrelation, they do not exist (under normal circumstances) alone.

(8) **Human organizations**: Human organizations are becoming entities by themselves: they show emergent properties un-derivable from properties of individuals. These systems, beside human individuals, also enclose other natural subsystems as well as human artefacts. Little is known about special properties that are not observable in human and/or other living beings, but they, uniquely, do not have to die.

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[1] *Knowledge about knowledge, thinking about thinking, enables us to transfer knowledge (so we can know about something without experiencing it), to have a historical perspective, to plan our actions, etc. – which are all blessings. But we may also know that something bad will happen as suggested by John Preston "... the nicest thing about NOT planning is that failure comes as a complete surprise, and is not preceded by a period of worry and depression" (http://www.eqconsulting.co.uk/services/strategic-development.php).*

(9) **Transcendental**: It is presumptuous to suppose that system complexity ends at the level of human race, so we cannot rule out the possibility of transcendental systems. These systems are left out of consideration in this dissertation, not because they are considered unimportant but, because they are little known and their consideration should be an investigation at least of size of the dissertation.

Level (8) is obviously formed as system of elements, which were the systems on the previous level. However, we can do this for other systems as well: (a) the population of individual systems are the *demographic systems*; (b) if other populations are added to a demographic system they become an *ecological system*; and (c) if we also include the time dimension to observe how an ecological system evolves, we get *evolutionary systems*. Before Darwin (1859 and 1871), the evolutionary systems have been regarded, according to the human-centred world-view, to grow towards the human being. Darwin eliminated this point asserting that evolution progresses *from* the primitive but *toward* no goal, on basis of natural selection, which, in struggle for existence, preferred the fittest. (Kuhn, 1962, pp. 171 ff) Boulding (1985) and Capra (1983) suggest that the direction of evolution has a vague goal of higher complexity and that concept of the *'survival of the fittest'* should be replaced by the concept of the *'survival of the fitting'*, shifting the emphasis from competition to collaboration.

When we examine systems – that is to say anything according to the previous discussion – we are often interested in processes. Processes are activities of the interrelationships of the elements involving changes of these interrelationships. For this dissertation four types of processes are distinguished:[1]

(1) In **deterministic processes** it is determined what output follows a particular input and it will exactly happen in 100% of repetitions. Small changes on the input will result in small changes on the output, which can be precisely calculated. The relationship of the input and the output is causal and can be given in form of a calculable function. If we would like to use the

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[1] *This categorization of processes in systems is developed as an original contribution during the present research and has already been published as a subsidiary result of a conference paper. (Baracskai-Dörfler, 2003)*

vocabulary of probability theory, we could say that there is an expected value only with zero dispersion. These are processes of elementary (classical) physics (mechanics of not microscopic, but also not astronomy-sized bodies); the language of description is the mathematical analysis.

(2) In **stochastic processes** the relationship between the input and the output is less exact. The latter can roughly be known from the previous; it can be described with its expected value and its dispersion, which is smaller by at least one order of magnitude. Small changes on the input will result in small changes on the output, which can be estimated, though not precisely calculated. There are some processes in the real world in which' uncertainty is innate; when he discovered this, Heisenberg ([1962](#), p. 12) cried out:

"Can nature possibly be as absurd as it seemed to us in these atomic experiments?"

To describe these processes we use *ex ante probabilities*. Disciplines of this kind of stochastic processes are e.g. the quantum physics and the chemistry; and the language of description is the probability theory. There are, however, other processes usually considered stochastic because we do not know them well enough; i.e. we cannot measure and/or control the values of particular parameters with precision. To describe these processes we can use *ex post frequencies*, which are usually later used to augur future values; this means that we use quasi-deterministic description assuming that the future will be the same as the past, dividing the different outcomes according to accumulated frequencies of mid-steps from past experience. Discipline of this second kind of stochastic processes is e.g. the production and operations management; and the language of the description is the statistics. It can be useful sometimes to distinguish between these two kinds of stochastic processes; the first can be called *probabilistic*, the second *statistic* process.

(3) In case of **chaotic processes** the dispersion is in similar order of magnitude than the expected value. A small change on the input may result in huge

changes on the output – the famous "butterfly-effect" from chaos theory, or, using the terminus technicus, sensitive dependence on initial conditions. (Gleick, 1988, p. 23) The equilibrium states in these processes are unstable. Imagine e.g. a ball balanced on the tip of the needle. If nothing moves (which is otherwise impossible), it could be there for ages; thus it is an equilibrium. It is, however, unstable; a lightest breeze or a gentle movement of the needle can result in the ball falling down. It is interesting to read Russell (1948, pp. 55-56) writing about instable states of balance, which obviously belongs to domain of chaos, even though he could never heard about chaos theory. Such processes often form smaller parts of processes that belong to the previous two categories on a larger scale. E.g. if we have a cup of coffee, it is easy to estimate its temperature tomorrow but it is nearly impossible in two minutes from now (Gleick, ibid, p. 24); we can know the climate of a place fairly well, while we are in great trouble with its meteorological predictions; as Boulding (1985, p. 36) claims:

"...the atmosphere, which seems like such a relatively simple system, actually turns out to be almost as complex as economics; indeed, the record of prediction of economists and meteorologists is highly comparable. I am not sure, but economists may do a little better."

The statistics and the probability theory are useless here; we could give estimations of the output like 12m±15m, which gives us nothing. To be sure, the chaotic processes do not resist modelling; only we are yet inexperienced in this field and have to realize that they are to be handled differently from the first two categories. We have to see that the conditions of the central limit theorem are not satisfied – if they were, the process would be stochastic or statistical – as the causes are not independent and not all of them are known; or there are so many of them that not all can be considered. This means that in this kind of processes even the same input may result in very different outputs. Probably here we also have processes in which the chaos is inherent and others where we only lack knowledge but at the state of the art these cannot be distinguished. Chaotic processes can be associated with the field of biology and especially with the genetics; the language

for description is only in early stage of development; there are various lines of this development generally named as chaos theory and one of the promising tools are the fractals. ([Gleick, ibid](#) and [Penrose, 1999](#), p. 98 ff)

(4) At the highest level of complexity we can find the **heuristic processes**, and we know even less about them than about the chaotic ones. Here the same inputs may result in completely different outputs. Using the terminology of probability theory we should say something weird like that there is only dispersion with no expected value – which of course makes no sense at all. In heuristic processes there are a plenty of effects that are not, and cannot be, taken into account. It is easier to say that there is 'something else' that determines the output – for example the free will. So this is the level of humans. The decision taker chooses an alternative not knowing all the consequences, although, an experienced decision-taker will guess the output, using unknown heuristics of her/his tacit knowledge. This is the territory e.g. of psychology and all the disciplines and each problem concerning the human as an individual person. This is the territory of this dissertation. We should not be misled by the result of a psychoanalyst, who finds the 'cause' of a certain mental problem of her/his patient; i.e. if there was a real causal relation, everybody affected by the 'cause' should have been facing the same problem. This is not the case. Such phenomena show a great complexity, which cannot be described as stochastic or even chaotic. However, according to Bertalanffy ([1969](#), p. 34) this is organized complexity as contrasted to disorder or unorganized complexity – this makes possible the insight of the decision taker. For the previous three types of processes a more or less formed mathematical toolbar is available (though it is quite underdeveloped for the chaos); on contrary, heuristic processes cannot be handled exactly (numerically). All we can do is to develop conceptual, qualitative models; we will probably develop an appropriate language for description as for the previous process types but for now we do not have one.

To examine the systems and processes described above, we have different methods at our disposal:

The first group are the hard or structured methods (Yourdon, 1989): Dataflow Diagrams (DFD); Data Dictionaries; Process Specifications usually in different forms of flowcharts; Entity-Relationship Diagrams (ERD); State-Transition Diagrams (STD); Project Management Tools like PERT, CPM, MPM. These methods are meant to be used for deterministic processes, though some versions are adapted to stochastic ones by introducing divisions according to statistical frequencies (or probabilities). Here we can also consider various tools of Operations Research and System Analysis/Engineering.

The second group are the soft methods. These are numerous, some of the most important ones (Flood-Jackson, 1991, p. 31 ff) are System Dynamics (SD), Viable System Diagnosis (VSD), Contingency Analysis, Interactive Planning, Critical System Heuristics (CSH), Soft System Methodology (SSM), and Strategic Options Development and Analysis (SODA). SODA, developed by Eden and Ackermann (Eden-Ackermann, 2001), and SSM, developed by Checkland (1999a, 1999b and Checkland-Scholes, 1999), are both sets of tools and methods with an approach and a meta-method operating on them[1]. The various simulations also belong to this group, often as realizations of one of the listed methods.

If we try to devise some kind of 'even softer' methods we could find ourselves in a situation that we are building models using metaphors and not following any kind of rules. Thus we cannot speak about methods in this category, only about ad hoc tools. (cf. Chapter 2.5)

There are two approaches which are very different from the previously-listed methods: **General System Theory (GST)**, originally conceived by Bertalanffy (1969), creates models presuming nothing else about the examined system but that they are systems, and the constraints involved. E.g. if there is a system with multiplying elements without limit, their number will follow an exponential function, if there

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[1] *In this sense, SSM is a methodology (cf. Section 2.5)*

is a limit, their number will increase according to a logistic curve. (Bertalanffy, 1969, pp. 60-63) **Total System Intervention (TSI)**, developed by Flood and Jackson (1991) for handling multiple interrelated systems, uses metaphors to indicate what level of complexity is assigned to a particular considered system from a particular aspect in a particular situation. E.g. if we want to solve a production problem, maybe we can use the machine metaphor for the financial department, the political metaphor for the management and the organic metaphor for the shop-floor. As it is emphasized by Clarke, Lehaney and Martin (1998, p. 297), the key feature of TSI is its use of multiple methods in a single problem context.

This section aimed to introduce briefly the huge area of systems. Systems are important in this dissertation for several reasons: Knowledge here is considered to be a hierarchical system. In particular the research focuses on level 7 (see human systems previously in this section), as it is human knowledge. The investigation examines individual and organizational value systems; the former is level 7, the latter is level 8. Knowledge increase is considered to be a heuristic process (level 4). Knowledge as system and knowledge increase as a process are modelled using a mix of GST and TSI. The language of description is metaphoric because, as it will be shown in Section 4.1.1, knowledge seems to be impossible to define. Symbols from mathematics are borrowed for greater convenience of description.

3.3. Value Systems

"Science has achieved some wonderful things, of course, but I'd rather be happy than right any day."

Slartibartfast[1]

One of the systems tackled in this dissertation is the value system, more precisely two value systems are examined: the personal value system of the individual increasing her/his knowledge and the organizational value system of the organization of which the individual is member of. These two value systems will be used to construct the MLW using rationality as introduced in Section 3.1 as a framework; i.e. the deci-

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[1] *Adams, Douglas (1979) The Hitchhiker's Guide to the Galaxy, Pan Books, London, p. 161.*

sion happens by comparing the decision alternative to the value system formulating expectation in advance and objections during the process.

This section aims to provide understanding of value systems in general and to describe the relationship of the personal and organizational value systems. These descriptions are examined more specifically in terms of knowledge (Section 4.1.9) and in terms of knowledge increase (Section 4.2.9) before the construction of the MLW. Value systems are presented as symbolic universes, which are shown using examples to be changing in time, ill-structured, non-additive, non-transitive. It is also argued that the organizational value system forms from individual value systems through their complex interaction but, once formed, they become independent.

Value systems are systems of values in full meaning of the term, belonging to level 7 and level 8, as described in the previous section, rather than only a simple list of preferences of values. In this section it will be argued that value systems feature muddled structures and that the value system of a group (organization) forms in a complex interaction of personal value systems of the group members. But what are the values? For present discussion, Bertalanffy's (1981, p. 13) definition is adopted:

"Values are things or acts which are chosen by and are desirable to an individual or to society within a certain frame of reference."

The inquiry into value systems is as old as anything the philosophers became engaged with; as the value system is about preferences, about telling what is good and bad, it is part of philosophy of morals, i.e. of ethics. In the present there is no space to start from pre-Socratics through Plato, Aristotle, the Epicureans, St. Augustine, Spinoza, to Kant, Hegel, Marx, and today to Damasio, Sen, Pirsig, and so on. Only the most relevant issues will be tackled to be able to examine those characteristics of value systems that are important for the present dissertation.

The utilitarian approach of John Stuart Mill (1861, p. 7) starts from the Greatest Pleasure Principle, i.e. that happiness is the only desirable thing; thus those desires and actions are good which promote happiness. In Mill's utilitarianism the value sys-

tem is presented as a static, well-structured hierarchy of values. ([Russell, 1946](#), pp. 701-703)

This is a pyramid-conception similar to (and going along with) the cumulative conception of knowledge before Kuhn's conception of paradigms. In this dissertation the value system is considered to be a constantly changing ill-structured hierarchy ([Hofstadter, 2000](#) and [Mérő, 1998](#)), which, in contrast to the pyramid, could be presented by a building similar to an Escher-graphic (Figure 11). First, individual value system is discussed, to show that it is nothing like a well-structured hierarchy; this is done mostly using examples. Then organizational value system is analyzed to show that, although it evolves from interaction of individual value systems, this is a complex interaction which cannot possibly be reduced to a simple algorithm.

It is rather easy to see that our preferences do change by time, so the hierarchy is not static. E.g. one can consider a higher salary to be more important than more leisure time, then one's opinion may change later (e.g. once having had a child) to opposite preference. We are also constantly subject to external influences trying to modify our preferences.[1] This is why Kotler (p. 10 ff) argues that we have to abandon the idea of the customer making free choices (cf. Section 2.7) and rather we should consider the influenced customer. It is more difficult to show that the value system is an ill-structured hierarchy, that the preferences are not transitive, not additive and neither symmetric nor anti-symmetric. These will be demonstrated here using examples.

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[1] *To be sure these influences are not constant: they change, some disappear, and new ones emerge – just think of the influence of the media. What is constant is our state of being under influence.*
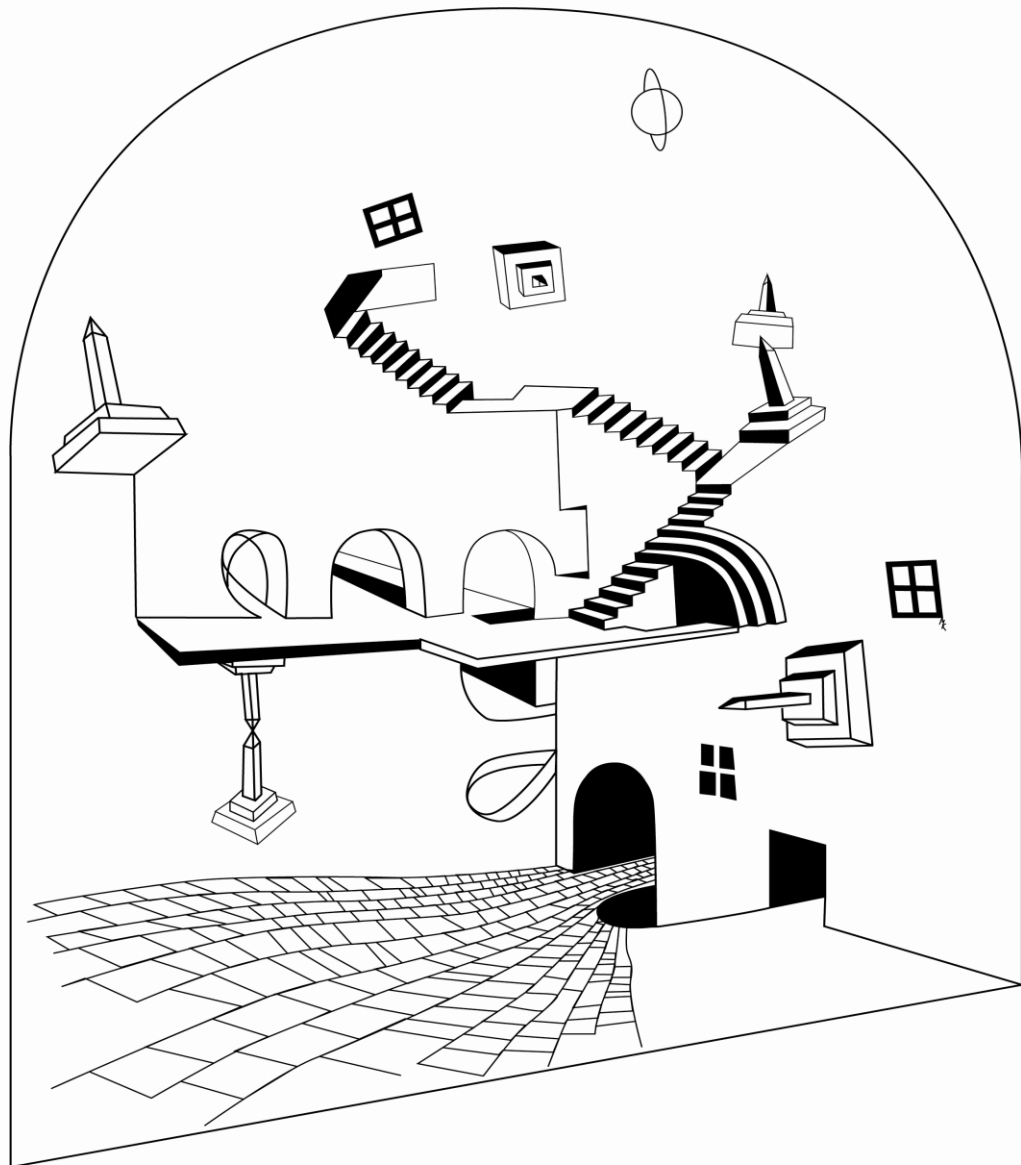
Figure 11: Hierarchy of values – nothing like a pyramid.

Two examples do illustrate that the condition of transitivity does not apply, one example of non-transitivity of «equal» preference and one for preferring one alternative to another. For a lecturer it may make no difference if she/he gets £3000 or £3001 for a development of a new curriculum for MBA students, it is also «equal» if she/he gets £3001 or £3002, and so on, let's say until £3499 or £3500. However, it makes difference if she/he gets £3000 or £3500. For another example consider someone wanting to write this dissertation. Let's say that one has two books to choose for reading, Hofstadter's "Gödel, Escher, Bach" and Minsky's "Society of Mind". One chooses the first one as she/he is looking for something to be used as a reference

about the muddled nature of hierarchies of the value systems. In other situation, the same person has to choose between the same book of Minsky and Asimov's "Foundation". One chooses "Society of Mind" to learn about artificial intelligence and human mind (e.g. for Section 3.7 of this dissertation). In the third situation our person chooses Asimov over Hofstadter to have some fun. Thus the loop is closed. The example may look trivial but it demonstrates that different situations may motivate the preferences differently, which, as is shown, may lead to different results.

It is very easy to find an example demonstrating the non-additivity of preferences.[1] Presume a person who has the following preferences: she/he likes whiskey but likes wine more and likes beer even more. If the preferences were additive then for sure she/he would prefer the mixture of beer and wine (the first two) to whisky (the third). Well, we do not have to know much about drinks to see that such person would be difficult to find.

If we compare the present examples to Simon's definition of well-structured problems at the beginning of Chapter 2, we see that the idea of well-structured hierarchies should be abandoned. Our value system is also affected by the limitations of our cognitive capacity (Slovic-Lichtenstein-Fischhoff, 1988, p. 727):

"... our values may be incoherent, not sufficiently thought through... we may have contradictory values... We may occupy different roles in life (parents, workers, children), each of which produces clear-cut but inconsistent values... We may not even know how to begin thinking about some issues... Our views may change so much over time (say, as we near the hour of decision or of experiencing the consequences) that we become disoriented as to what we really think."

According to Bertalanffy (1981, p. 17) values belong to the symbolic universes of human and thus they are level 7 and 8 systems (Section 3.2):

"The fact that man lives in a universe, not of things, but of symbolic stand-ins for things, indicates the difference between biological «values» and specifically human

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[1] *The present example was used by Zoltán Baracskai on an MBA course.*

values. Compared to the biological traits or «values» which may be categorized as either «useful» or «harmful» for the survival of the individual and the species, what we call human values are essentially symbolic universes that have developed over the course of history. This conceptualization is applicable to any field of human activity, be it science, art, morals, or religion. These symbolic universes may be adaptive and utilitarian in the biological sense, as when technology allows man to control nature. They may be indifferent, such as Greek sculpture or Renaissance painting, which hardly can be claimed to have contributed toward better adaptation and survival. On the other hand, they may be outright deleterious if the breakdown of an individual's «little» symbolic universe leads him to commit suicide, or if the conflict of larger symbolic worlds leads to war and extermination on a large scale."

By recognizing this we face the problem of measuring. If our values belong to the world of symbols they cannot be measured on convenient interval and proportional scales. The measurability of individual preferences (utility functions, indifference maps, etc.) would be desirable but the measurement is also subject to value judgment, as no neutral criteria of such measurement could be devised. (Sen-Williams, p. 6)

The value system can be investigated by observing human value judgments, i.e. our choices. Harsányi (1977, p. 55) distinguishes the manifest preferences (this is what we can observe when observing choices) and the true preferences (what the person would have if all the relevant information was available, there was no mistake in reasoning, no false beliefs, she/he was in the most composed state of mind, etc.). Polányi (Polányi-Prosch, 1977, p. 5) goes further and takes side with Sartre:

"... the existentialists are closer to the truth in their view than any of the other academically popular Western philosophies, because there is a sense in which it is true that determinative reasons cannot be given for every choice – in fact, not for any choice."

The problem of fair division shows us what we can gain by observing choices. It can in principle be represented in the two-person cake-sharing, when one divides the cake (goods, anything desirable) into two parts and the other chooses. This example

is also good to show how such situations could be used to find out more about the individual's value preferences: e.g. if the first person divides the cake unequally and observed whether the second would choose the smaller or the bigger part, the first could draw conclusions about the second's personality or mood – according to the first person's interpretation of the second person's value system. No less, no more.

Von Neumann and Morgenstern (1964) showed that the misrepresentation of their preferences can be directly profitable to individuals; consider, e.g. the voter, who prefers the candidate of a minor party but votes for the less undesirable major party candidate just not to get her/his vote lost. The examination of choices also involves considering the question of freedom as it was done in Section 2.7.

This all makes us realizing that even if we had a kind of well-structured value system, we would never be able to recognize it as such and thus it is more appropriate to assume a muddled hierarchy. Hammond, Keeney, and Raiffa (1998) have shown that our choices are to a high extent determined by our perception, which they argue to be traps. As value systems are highly individual, Baracskai (1998, p. 70) calls them moral compasses.

Having reviewed the features of individual value systems, it is now time to examine how organizational value systems can be derived from the individual value systems of the members of the organization; actually, it is not discussed how they *can* but rather how they *cannot* be derived.

According to standard approach to such investigations in economics, the individual values are taken as data, thus they are not to be altered by the decision taking situations and processes themselves – which presumption can be asserted. According to Bergson (cited in Arrow, 1963, p. 4) value judgments are present in the choice of the mathematical form of aggregating individual preferences into a social one.[1] The used value judgments are not necessarily consistent with each other; even a single value judgment can be self-contradictory as shown in the *"voting paradox"*. In his

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[1] *Actually the original statement is about the "different mathematical forms of the social utility function in terms of individual utilities" but this is only a form of expressing preferences used in economics.*

impossibility theorem worth a Nobel's prize Kenneth Arrow ([1963](#)) showed that it is in principle impossible to construct an algorithm for aggregating individual preferences into an organizational (social) one.

It seems reasonable to accept that the individual value systems are muddled hierarchies of values and that the value system of an organization is born from complex interactions of personal value systems of its members and it is also influenced by other organizations, which can be parts of the organization or include it or be in interaction with it. The situation is further complicated by the fact that although the organizational value system is formed from the interaction of individual value systems of its members, after the formation it somehow becomes independent. This can be illustrated by a well-known experiment with monkeys mentioned by Hamel and Prahalad ([1994](#), 55-56) in which monkeys got a cold shower from overhead when trying to climb the pole in the middle of the room to get the bananas suspended from the top. They learned quickly not to try to get the bananas; then the monkeys were replaced one by one – and still no one touched the bananas. It became part of their group value system that it is bad to try to get the bananas.

So far we have seen that the individual and the organizational value systems are very complex systems, distinct from each other and they cannot be constructed from each other using an algorithm. What is the relationship between the organizational value system and the personal value system of a member of the organization? We cannot suppose that they are the same but some similarity is needed; the two value systems have to be compatible. If the person cannot accept the organizational value system she/he leaves the organization; if the organization cannot accept the personal value systems of its members it gets rid of them; the two value systems also influence each other and thus they may, both or only one of them, alter.

The individual and organizational value systems are used in Sections 4.1.9 and 4.2.9 to describe the value of knowledge and knowledge increase. These are then used in Section 6.2 to describe the MLW; and for the model the mutual influence of the two value systems is also examined in terms of knowledge and knowledge increase. This means, that the MLW is concerned with two value judgments about new knowledge: one from the viewpoint of the individual and another from the viewpoint

of the organization. The individual and the organization not only judge the new knowledge but also influence each other to change their judgments.

3.4. Cognitive Processes and Memory

> *"The basic reason for studying cognitive processes has become as clear as the reason for studying anything else: because they are there. Our knowledge of the world must be somehow developed from the stimulus input; the theory of eidola[1] is false. Cognitive processes surely exist, so it can hardly be unscientific to study them."*
>
> *Ulric Neisser[2]*

The statement is not only quoted to justify the significance of cognitive processes being investigated but also to give first impression of the field, where such statements appear – i.e. that one feels it necessary to explain why one investigates cognition (cf. Section 2.8). As this dissertation is concerned with knowledge increase, the relevance of the topic can hardly be doubted; but more particularly it will be used to describe the elements of knowledge (Section 4.1.2) and the process of knowledge increase (Sections 4.2.2 and 6.1).

The rationale of the state-of-the-art of the field is given through a very brief historical overview of cognitive psychology, which is followed by a description of cognitive processes similar to information processing models common in cognitive psychology (actually the presented model is an integration of several of these models), where the memory is the storage. In this section only the short-term memory is discussed; the enquiry into long-term memory belongs to the third cycle of investigation (see Appendix 2) as it is the basis for describing the knowledge levels, and will be presented in Section 4.1.8. The approach of cognitive psychology adopted in the present dissertation belongs to constructivism. This constructive nature of cognition is used to explain the process of knowledge increase in Section 4.2.2, i.e. how the exist-

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[1] *Ancient theory, according to which our minds receive and store copies of objects. (Neisser, 1967, p. 3)*

[2] *Neisser (1967, p. 5)*

ing knowledge of the person and the new knowledge she/he is acquiring interact to form her/his increased knowledge.

Psychology began[1] with Wilhelm Wundt's psychology laboratory in Leipzig (Anderson, 2000, p. 7) and – as Anderson claims – Wundt's psychology was a cognitive psychology. Wundt used the method of introspection performed by highly trained participants. American psychology had only a weak try on introspective (also called structuralist) psychology – and into some other directions – to find its way for a long time following Thorndike's (1911) footsteps building the behaviourist school of psychology. As behaviourists were not at all interested in what is going on in human – or other – mind only in the changes of behaviour (Watson, 1929) the problem of cognition disappeared from the their psychology (see more details in Section 4.2.1). In Europe the behaviouristic psychology did not become dominant, there were separated investigations going on, Bartlett (1932) was interested in remembering and social psychology, Piaget (1929, 1959) in developmental psychology, Freud in psychological drives, and there was a strong school of Gestalt psychology in Germany founded by Wertheimer (Köhler, 1959); all these schools became important for the later basis of modern cognitive psychology. World War II had a twofold impact on the development of cognitive psychology:

(1) A number of Gestalt psychologist emigrated to the United States and some later became prominent, causing a significant impact not only resulting in renewed interest in cognitive approach but also in development in more sophisticated versions of behaviourism (see Section 4.2.1).

(2) Most of the early behaviourists were interested in education but the problem of teaching was not only cause of the rise but also of fall of behaviouristic psychology; i.e. it was unable to grow up to the urgent need of training soldiers to use sophisticated equipment or to cope with the problem of attention breakdown (Anderson, 2000, p. 10)

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[1] *I.e. it became separated from philosophy as independent discipline, though the interest in problems of psychology can be traced back to the first records of thinking, e.g. to Plato and Aristotle.*

After the war cognitive psychology showed a steady growth, to become one of the Cognitive Sciences, as we know it today (see Section 2.1). The modern cognitive psychology borrowed its approach from information theory of Shannon (Shannon-Weaver, 1963) and Wiener (1961)[1] to study cognitive processes; and it has gradually shifted from *"channels"* and *"bits"* of information measurement towards information processing model (Neisser, 1967, pp. 7-8), which is becoming more and more «human».

"... the term «cognition» refers to all the processes by which the sensory input is transformed, reduced, elaborated, stored, recovered, and used. It is concerned with these processes even when they operate in the absence of relevant stimulation, as in images and hallucinations. Such terms as sensation, perception, imagery, retention, recall, problem-solving, and thinking, among many others, refer to hypothetical stages or aspects of cognition." (Neisser, 1967, p. 4)

To put it more simply, cognition is what happens between the stimuli and the response, but neither the stimuli nor the response are necessarily present. Before turning to detailed description of the process of cognition, it will be shown that the cognition is by its nature a constructive process.

Stimuli are signs reaching our sensory mechanisms, and in the first part of the cognitive process called perception they are converted into sensations. The process of cognition is not based only on reality but, as constructivist theorists[2] claim (Eysenck, 2001, pp. 26-29), an interaction between the reality and the observer, i.e. her/his knowledge, expectations, beliefs, feelings, emotions. It is reasonable to assume that if perception is constructive, all cognitive processes are necessarily constructive; this is even more obvious in case of symbols, which are special signs without a definite meaning. (cf. 2.7)

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[1] *Wiener (1954) later felt responsible for the inappropriate use of his ideas and became the moral conscience of cybernetics.*

[2] *I.e. it is the actual reason that they are called constructivists, as they see perception (and other cognitive processes) to be active and constructive.*

Bruner and Postman (1949) realized that if our expectations play a role in the process of perception, then incorrect expectations may lead to perceptual errors. They designed an experiment[1] in which cards are shown to experimental subjects; and some of the cards are irregular, e.g. black heart six. First, when the time allowed to see them was short, the experimental subjects classified the irregular cards as some similar regular ones, e.g. the black heart six was classified either as (red) heart six or as (black) spade six. As the allowed time increased, most of the subjects noticed that 'something was wrong' with the irregular cards and the time had to be further increased for them to realize 'what was wrong', although different people needed significantly different amounts of time. It is easy to find further evidence to the constructive nature of cognition, e.g. we often read a text without noticing a mistyping, or we can read Figure 12 giving different interpretation to the same character in different context. A criticism of the constructivist approach will be presented in Section 4.1.4 as there will additional concepts introduced and they are needed both to understand and to refute the criticism.

Source: Selfridge (1955)

Figure 12: Reading in context.

There is one important note on cognitive processes and especially on perception as examined nowadays: Almost exclusively processing of visual and auditory signs is examined, there is very little known about the other sensory inputs (e.g. some can be found in Baddeley, 1999, pp. 180-181) and this is probably the reason for some features of the models, especially the models of memory.

The generalized model of cognition shown on Figure 13 integrates the model of cognition of Lachman, Lachman, and Butterfield (1979) with the memory-model of Atkinson and Shiffrin (1968) and the model of working memory of Baddeley (2000,

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[1] There are numerous other experiments supporting the argument but the presented one is probably the best known.

2003), and it also considers the constructive nature of cognition as it was presented. This model contains nothing new; its purpose is to integrate the above models into a single entity. Based on the model, the process of cognition can be described as follows:

(1) The signs from the environment first reach our sensory registers; there are three of them, the visual, the auditory, and the haptic.[1]

(2) If they catch attention they are transferred into the short-term memory (STM). As it will be discussed in detail in the next section, not all the signs catch attention and this seems to be because of the limited capacity of the STM; the STM will be discussed later in this section.

(3) STM was considered to be a store only, until Baddeley (1998, 1999) has shown that complex processes should be assigned to it; to emphasize this difference he introduced the term of working memory. The working memory, besides storing, also encodes and organizes the arriving signs, at the same time retrieving knowledge from the long-term memory (LTM) and organizing it; the thinking, the decisions happen here as well; and all these processes are controlled by the Central Executive.

(4) The encoded knowledge is transferred from STM to LTM, where it remains 'permanently'. It keeps changing and fading and eventually disappears from the LTM.

(5) The effect of emotions, feelings, intentions, expectations happens in relation with STM and LTM and it is observable only in its consequences; i.e. can be guessed from the response.

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[1] *According to the previous note there might be more types of sensory registers if more was known about the processing of other types of sensations.*
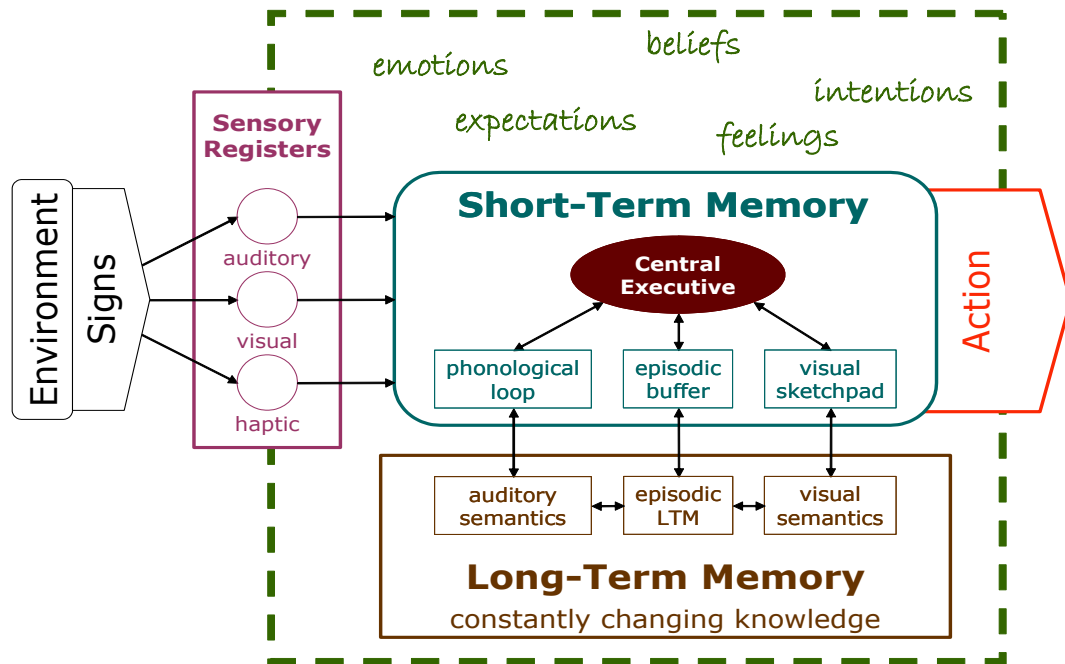
Figure 13: Generalized model of cognition.

The previous description was that of a 'complete' cognitive process, its parts can be identified as typical cognitive processes. E.g. the perception starts with the input signs and ends with encoding in working memory; the thinking happens in interaction of STM, LTM and possibly involving beliefs, emotions, feelings, intentions, expectations. The relationship between the beliefs, emotions, feelings, intentions, expectations and the STM and LTM is bidirectional, and thus, the constructive process is also bidirectional, as Maslow (1971, p. 161) puts it:

"As Emerson said, «What we are, that only can we see.» But we must now add that what we see tends in turn to make us what it is and what we are."

As in the previous model of cognitive processes there are storages, which are parts of memory, the description of cognition would not be complete without explaining memory. Scientific enquiry into memory began when Ebbinghaus (1913) suggested that it could be studied experimentally. He elaborated infinitely simple tasks, e.g. to remember and reproduce meaningless letter sequences, to minimize the effect of existing knowledge. His approach was overthrown by Bartlett (1932), who argued that by excluding the meaning the most important feature of human memory is excluded. He gave meaningful texts to his subjects and observed that, when they recall the text, they often substitute words with others of similar meaning. Bartlett (1932) also made

pioneering contribution to understanding of organization of memory, as it will be discussed in Sections 4.1.2 and 4.1.8. Neisser (1978, p. 4) acknowledges Bartlett's advances but he warns:

"In my view this work is still somewhat deficient in ecological validity – hardly anyone memorizes one-page stories except in the course of psychological experiments – but it is still a great step forward."

As he puts it, all these years of studying memory did not get us any closer to understand the everyday properties of it, thus he urges the scientists to observe memory in a natural context[1] (Neisser, 1978, p. 11):

"Unfortunately, it turned out that «learning» in general does not exist: wasps and songbirds and rats integrate past experiences into their lives in very different ways. I think that «memory» in general does not exist either. It is a concept left over from a medieval psychology that partitioned the mind into independent faculties: «thought» and «will» and «emotion» and many others, with «memory» among them. Let's give it up, and begin to ask our questions in different ways."

Until the 1960s there was no discussion of whether the STM and the LTM involve two separate systems or not, the Atkinson-Shiffrin (1968) model was widely accepted, for the simple reason that people investigating STM did not work on LTM and vice versa. (Baddeley, 1999, p. 34) Now, there are alternatives suggested: Chase and Ericsson (1982) defined STM as the currently active subset of LTM nodes, considering a single memory system, while, on the contrary, Baddeley (1999, p. 34) believes that there should be more than two systems, as the STM is an

"amalgam or alliance of several temporary memory systems working together".

What the different models agree about is the limited capacity of STM. The first and most used description of the limitation is presented by Miller's (1956) magic

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[1] *Hence this is also the subtitle of his recent book (Neisser-Hyman, 2000)*

number 7±2, meaning that we can store 7±2 pieces in STM;[1] similarly Chase and Ericsson ([1982](#)) put limitations on the number of LTM nodes that can be activated. The most elaborated conception of STM is Baddeley's working memory. In its early version ([Baddeley, 1998](#)) it consisted of the phonological loop (storing and processing auditory signs), the visuo-spatial sketch pad (responsible for visual signs)[2] and the central executive (in charge of organization and co-operation of processes); later ([Baddeley, 2000](#) and [2003](#)) an episodic buffer was added (to deal with the meaning). This model attributes the capacity limit of STM to the central executive. For this dissertation, only the existence of the capacity limit is important – no calculation is done with or about it.

There is also substantial experimental evidence of the invariability of the capacity limit of STM, often involving examination of mnemonists or memorists[3] (e.g. [Neisser-Hyman, 2000](#), pp. 475-518). Their reports suggest that they chunk the digits (or other) to be memorized but they still hold 7±2 in their STM. The subject of one of the most famous investigations, SF ([Chase-Ericsson, 1982](#)) grouped the digits associating them with running times. These observations sheds light on interesting nature of the capacity limit of STM, namely that the number of chunks is what is invariable, not the number of digits as it could be assumed.

The LTM can be examined from various aspects (e.g. [Schacter, 1996](#)) but only two are relevant from the viewpoint of this dissertation: the representations of knowledge and the capacity of LTM. The representations of knowledge are used in the process of modelling knowledge as a picture that guides the process; more precisely, this is one of the considered knowledge typologies. These representations appear in Section 4.1.7 from the viewpoint of knowledge and in Section 4.2.7 from the viewpoint of knowledge increase. The capacity of LTM is used to describe the

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[1] *The pieces are the cognitive schemata introduced by Bartlett ([1932](#)) and will be discussed in Section 4.1.2.*

[2] *As it was noted previously, we do not know much about the processing of other types of stimuli.*

[3] *Neisser ([1982](#), p. 475) distinguishes these two – so that memorists are people with good memory and mnemonists are people using mnemonic devices – but the two terms are usually used interchangeably in literature.*

knowledge levels, examining how the knowledge increase of people at different knowledge levels differs. This analysis takes place respectively in Sections 4.1.8 and 4.2.8.

The description of cognitive processes and the STM are used as a general background for modelling the system knowledge and the process of knowledge increase, and the constructivist approach described here is one of the basic features for understanding this process.

3.5. Attention

> *"The moment one gives close attention to any thing, even a blade of grass it becomes a mysterious, awesome, indescribably magnificent world in itself."*
>
> *Henry Miller[1]*

This section contains only a general discussion of attention to prepare the ground for modelling attention (MA) in Chapter 6.4. Further preparatory discussion is provided in the next section, which is concerned with the motivational and the cognitive factors of attention.

The nature of attention is described here on the basis of experimental results from literature; and there are also references to STM (introduced in the previous section), as the capacity limit of STM provides capacity limit for attention as well. Actually even some books introducing cognitive psychology contain little apart from the topics of attention and STM (e.g. Neisser, 1967). The focus of the section is on distinguishing between the focal or front-of-mind attention and the background or back-of-mind attention. Before the end of the section an exercise is described, which was designed during the research and, considering its outcome together with the results from the literature, it provides better understanding of the nature of attention as well as refinement of the literature-based description. The section ends with the list of the features of attention.

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[1] *http://en.thinkexist.com/quotes/henry_miller/*

According to Davenport and Völpel (2001, p. 212), attention is probably the hottest topic of knowledge management today:

"... within knowledge management, attention management has become the most important success factor."

The reason for it is easy to understand: they identified attention as the bottleneck of the performance improvement of white-collar workers. Because of the importance of this issue we are willing to pay for it (or give something in exchange), and so some authors speak about attention economy. (E.g. Davenport-Beck, 2001) Most efforts to-day are concerned with modes of catching the attention, as matter of fact there is a whole industry around this – the advertisement industry.

The first trouble arises when we try to define attention or to find an appropriate definition. One of the early discussions on attention comes from William James, the greatest exponent of functional psychology and the pioneer of the experimental approach in his monumental Principles of Psychology (James, 1890). He introduced the subject saying (pp. 403-404):

"Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others."

In many books, attention as such is not defined at all, only some of its components or aspects, e.g. Neisser (1967) focal and divided, visual and auditory attention. Davenport and Beck (2001, p. 20) give the following definition:

"Attention is focused mental engagement on a particular item of information. Items come into our awareness, we attend to particular item, and then we decide whether to act."

On the following pages, however, they distinguish between two types (this is along one dimension and there are two other dimensions which are not relevant here), the *front-of-mind* and the *back-of-mind* attention (pp. 22-24) and then they use

these categories throughout the book. The first type is conscious, focused and explicit, while the latter can engage with a number of (they say dozens but here it will be argued that it is 6±2) different subjects (p. 23)

"that will never come into your conscious awareness unless something unexpected occurs."

It can be noticed that their original definition describes the front-of-mind attention only. In the following discussion the attention can be regarded as momentary openness to receive signs, while the distinction between front-of-mid and back-of-mind attention is adopted in the presented form.

Experimental inquiry into attention began with Cherry's (1953) interest in the so called "cocktail party problem".[1] His experimental subjects were listening to two different messages from the left and right headset speaker[2] and later they were asked questions about them. If they were told in advance which message would they be asked about, they were very good at answering those questions but had only some very general recollection of the other message (e.g. they usually did know if the speaker was female or male but not noticed if the language of the message was changed from English to other language). Numerous further experiments are discussed e.g. by Anderson (2000, pp. 75-81).

The described phenomenon above is called focused (Eysenck, 2001) or focal (Neisser, 1967) attention which can also be identified with the front-of-mind attention (Davenport-Beck, 2001). The first explanation of front-of-mind attention is provided by Broadbent's (1958) *filter theory*, which suggests that there is a selection immediately after the sensory registration, why the model is also called an early selection model. According to the model, one receives multiple sensory inputs and at the early stage of processing one selects a single one of them on basis of physical characteristics for further processing. Treisman (1964) argued that besides physical characteristics the selection is also based on meaning, that the selection happens

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[1] *The problem of how can we follow just one conversation with several people/groups talking around. (Eysenck, 2001)*

[2] *Tasks of this sort are called dichotic listening tasks.*

later, not immediately after the sensory registration and that the filtering does not eliminate completely the non-selected signs, but rather their processing is reduced or attenuated; thus he named his model *attenuation theory*. There is a third model, the pertinence theory, in which Deutsch and Deutsch (1967) proposed that all the signs are fully processed, and the most important one is responded to; as the selection in this model happens just before the response, it is also called the late selection theory. The most accepted of the three models today is the attenuation theory (Eysenck, 2001, pp. 118-119), and Broadbent's filter theory, although superseded today, had an enormous influence on cognitive psychology providing an early information processing model of a mental process (Eysenck, 2000).

The described and similar experiments as well as the models suggest that the attention cannot be distributed. On the other hand we can drive and listen to music while also thinking of our next meeting at the same time; or we can watch our children do their homework, talk on the phone and write an instant message to some friend simultaneously; and there is also a substantial experimental evidence of this sort. (E.g. Eysenck, 2001, pp. 130-148) This second type of phenomena is usually attributed as divided attention (Eysenck, 2001, p. 130) and it remarkably resembles the back-of-mind attention of Davenport and Beck (2001). So can the attention be distributed or not? Is there some real multitasking or only fast switching between the processes? As usual, the answer is not so simple.

We have seen so far that there is some kind of selection of process and that only one can be in the focus, but it is not yet clear what happens to non-attended processes. In another experiment (Wright-Anderson-Stenman, 1975) subjects also listened to two different messages and were told to pay attention to only one of them, but there were special words in the non-attended message, which were previously associated with electric shocks. The listeners, even though not aware of the situation consciously, usually responded physiologically, and also for the words with similar sound or meaning. This suggests that the non-attended processes are not completely stopped and also points out the role of the cognitive content similarly to the attenuation model. The importance of the cognitive content is further emphasized by Anderson (2000, p. 98):

"People can process multiple perceptual modalities at once or execute multiple actions at once, but they cannot think about two things at once."

Similar to the front-of-mind attention there are also models describing the back-of-mind attention; major findings of these are summarized by Eysenck (2001, pp. 131-134). There are three factors identified to influence multi-task performance:

(1) Task similarity: One can more likely perform two (or more) tasks at the same time if they are more different (e.g. driving and talking), similar task seem to disturb each other. This observation gave rise to Wickens' (1984) model of multiple resources, according to which there are several pools of resources and different processes can be performed at the same time if they use different pools of resources. Allport, Antonis and Reynolds (1972) used the similarity of tasks to explain the mistaken conclusion of Broadbent's (1958) filter theory (i.e. that the total filtering occurs due to similarity of the two tasks in dichotic listening).

(2) Practice: Multi-task performance improves drastically with practice, so Shiffrin and Schneider argue that automated processes require no attention at all. (Schneider-Shiffrin, 1977 and Shiffrin-Schneider, 1977) Spelke, Hirst and Neisser (1976) have also shown that even two very similar tasks can be performed simultaneously if practised enough; their subjects were to read a text for comprehension while copying dictated words and at a later stage also writing down the categories of the dictated words. According to Neisser (1967, p. 101) the automated processes are carried out preattentively, i.e. not demanding focal attention. Logan (1988) devised a model called *instance theory* to explain development of automaticity and summarizing it; he suggests that the novice performance is limited by lack of knowledge rather than by the lack of resources. Anderson (2000, p. 98) explains automaticity as reducing the central cognitive component through practice.

(3) Task difficulty: Novel or more complex tasks lead to a strong decrease in multi-task performance. Several of previously mentioned experiments (e.g. Spelke-Hirst-Neisser, 1976) already provide some account; and there were

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others specifically designed to pursue this aspect; e.g. Sullivan (1976) increased the difficulty of the dichotic task by reducing redundancy of the shadowed auditory message, which resulted in decreased accuracy of detecting target words in the non-attended message. Eysenck (2001, p. 133) explains the degree of the performance decrease by suggesting that the resource demand of two tasks together can be more than the sum of the demands due to co-ordination demand. Thus the task difficulty links to the task similarity and also links to automaticity as more difficult tasks require more practice. The trouble with this issue is that we cannot define and measure the task difficulty, so it is often overlooked by researchers.

As it will be shown in the following paragraphs, we often combine two tasks into a single one of higher complexity, and then we can practise this more complex task in order to enhance our performance. The forthcoming examination leads to the construction of a model by integrating the previously introduced ones providing satisfactory explanations for all the introduced phenomena. Naturally the model is speculative and uses wider basis than the observations and therefore it is offered for debate and testing on previously not encountered phenomena.

Consider the following two exercises:

(1) Hold your arms upright and start rotating them in opposite directions. (See Figure 14, left) The more difficult version of this exercise is to change the direction of the rotation for both arms from time to time, e.g. four rotations in one and four in the other direction (the two arms are always rotated oppositely).

(2) Fold your hands and put the two thumbs tip to tip (not touching, only facing each other); now try to twiddle them in opposite directions (see Figure 14, right), i.e. the same task as in the previous exercise, only this time with thumbs instead of arms. If you succeeded, try also the more difficult version, similar to the previous exercise.[1]

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[1] *Please, also send me an e-mail to make a record of it, as there are insufficient observations of those who succeeded.*
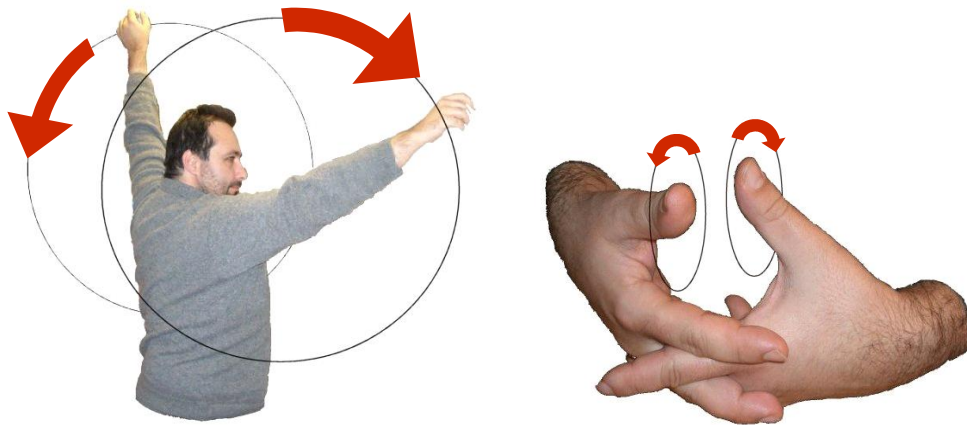
Figure 14: Two exercises on attention.

The first exercise was observed on about hundred occasions. The success-rate (i.e. the percentage of those who were able to perform it with no or almost no difficulty) was well above 90%. The second exercise was observed on more than fifty occasions and there was only one person who succeeded on the first attempt and one more after practising for a short time (only few subjects tried to improve their performance by practising.) The difference is significant, even if we take into account that the first exercise was mainly observed involving handball and volleyball players, who are supposedly more skilled in such movements.

More interesting than the success-rates were the observation of how the subjects tried to perform the two exercises. The subjects successful in arm-rotation always started at the same time with both arms, i.e. performing one complex task, instead of two simple ones. Once they succeeded in it, they were able the make conversations and watch environment, etc. Almost all subjects in the thumb-twiddling exercise tried to twiddle one thumb first and then the other one. All of them were able, without any difficulty, to perform traditional thumb-twiddling and none of them tried to do it starting their thumbs one-by-one. Several subjects tried after explanation to repeat this exercise as a single complex task and were more successful than previously. They usually made one or two circles successfully and then lost the rhythm. If they were told something they lost the rhythm as well. The loss of rhythm usually involved (re-)turning to traditional thumb-twiddling.

What can be concluded from the two exercises on basis of previously discussed models? Once a task is being performed in focus, it can be 'pushed out' from it to continue it unattendedly. If there is a routine which is similar to the task that is to be performed, the routine can override once the task is not in the focus. Two similar tasks can be performed simultaneously only if they are combined into a single more complex one; if one pushes a task into the unattended realm and tries to perform a similar one in focus, the focal task overrides the unattended one (similarly to the routine) by automatically incorporating it into a more complex task while modifying it at the same time. Similar conclusions can be drawn observing the exercise in which one is making circles on one's belly with one hand while patting the top of one's head with the other hand.

Considering the previously introduced models and explanations, as well as the two exercises, the following model is suggested:

(1) The front-of-mind attention is exclusive; therefore it must use sequential processing; involving perhaps some modified version of Broadbent's (1958) filter to include also filtering by meaning.

(2) The back-of-mind attention can be directed to several processes at the same time, thus it may involve parallel processing. Only automated processes can be controlled by back-of-mind attention.

(3) A strong sign can bring a back-of-mind process into the front-of-mind as suggested by Davenport and Beck (2001, p. 23) or can even elicit response without (or a moment earlier than) coming to the front. This means that back-of-mind attention keeps the doors open to strong signs.

(4) There is a limit also to number of processes in back-of-mind attention, probably 6±2 according to Miller's (1956) model, while the impossibility of performing two similar tasks suggests that the limitation by resource pools (Wickens, 1984) apply to the two attention types together.

(5) One way of coping with similar tasks is the combination of two or several simple tasks into a single more complex one, as suggested by the two exercises examined. This happens using the front-of-mind attention and, once

practised enough to achieve automaticity, it can be 'pushed' into the back-of-mind sphere.

(6) Front-of mind attention seems to be somewhat weakened by the simultaneous processes in back-of-mind attention except if all the processes in our attention are concerned with the same thing, e.g. thinking about what to write next in this dissertation, typing it and looking for a reference in literature. In this case we have all our attention focused which Davenport and Beck (2001) compare to Csíkszentmihályi's (2002) flow experience. (See next Section)

This list of features describes attention and how it is understood henceforth in this dissertation. This approach to attention will be used in one of the models, the MA (Section 6.4), which is about the attention that the person is able to pay during the knowledge increase. Based on this view of attention the factors determining how much attention the person is able to pay are examined in the model. Two groups of factors will be considered, the motivational and the cognitive factors. Arguably, other factors could also be considered, this will be acknowledged but not investigated due to the limitations of the present research. The following section prepares the background for the two considered factors.

3.6. Motivation and the Flow Experience

> *"Money was never a big motivation for me, except as a way to keep score. The real excitement is playing the game."*
>
> *Donald Trump* [1]

This section discusses the two related areas that will be used as factors of attention in the model of attention (MA) in Section 6.4. The MA is concerned with *sustaining* not with *catching* attention – i.e. it will be assumed that the person is willing to pay attention. The reason for this is that another model developed here, the MLW, is about the willingness of the person to acquire the new knowledge, so the questions is

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[1] *http://en.thinkexist.com/quotes/donald_trump/*

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how much attention one is able to pay if one is willing to. Thus only the content theories of motivation are relevant for this investigation. In particular, Maslow's motivational theory is considered but it is also shown that it does not contradict Alderfer's model, although it is often presented like that in the literature. Maslow's original will be restructured in this section for the more convenient later use without modifying its meaning. Here a bit of diversion is committed, i.e. the Maslow-model is followed by a discussion about love that is seemingly irrelevant. However, it will play a significant role as part of the restructured model of motivation; it will be used to describe the social level of motivation (from merging Maslow's 3-4 levels), and it will be crucial for describing the motivational factors of attention in the MA (Section 6.4).

The model of Flow experience is introduced in a simplified version only, as a balance between the expectations and knowledge; i.e. this is the only relevant aspect for the present research. Later, in Section 6.4, a transformed version of the Flow model will be used, which cannot be introduced here because, for the transformation, the conception of cognitive schemata is needed, which will be introduced in Section 4.1.2.

When starting to develop his theory of motivation, Maslow aimed to introduce a model which is human-centred (i.e. rather than animal centred), holistic (i.e. considering the whole person)[1] and based on classification (rather than listing) of drives. (For the full account see Maslow, 1943a.) His model became not only the foundation of his lifework but also the most cited piece of motivation literature and one of the bases of "Third Force" or humanistic psychology and of dynamic psychology. (Maslow, 1987, p. xi and p. xxxiii)[2]

Maslow (1943b, 1954, etc.) classified the basic needs into a five hierarchical levels:

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[1] *To use Maslow's (1987, p. 3) own example: "It is John Smith who wants food, not John Smith's stomach. Furthermore satisfaction comes to the whole individual and not just to a part of him."*

[2] *Reference is to Robert Frager's "Preface to the Third Edition" and "Foreword: The Influence of Abraham Maslow" in this posthumous edition of Maslow's work.*

(1) *Physiological needs*, when they appear, dominate the organism. Many of them are needed to maintain the level of some material within the organism, like oxygen, sugar, vitamins through homeostasis, though it is not demonstrated for all of the physiological needs (e.g. sexual desire, sleepiness) to be homeostatic. It is impossible as well as useless to try to make a full list of needs in this category.

(2) *Safety needs* appear when the physiological needs are fairly gratified. They are similar to the previous group; they can also dominate the whole organism although in less degree. These are the security, the freedom from fear, strength in the protector, and so on. Similarly to the previous category we cannot make a full list of safety needs.

(3) *Belongingness and love needs*, when they are unsatisfied manifest themselves in longing for relation with other people in general. Love needs involve both giving and receiving love and should not be confused with sexual need which is a physiological one. There is a little scientific knowledge on belongingness but its lack is manifested in psycho- and sociopathology.

(4) *Esteem needs* include self-esteem as well as esteem of others. Its satisfaction leads to feeling of self-confidence, of being useful and necessary in the world.

(5) *Self-actualization* refers to our behaviour to develop a new discontent and restlessness unless we are doing what we are fitted for (Maslow, 1987, p. 22):

"Musicians must make music, artists must paint, poets must write if they are to be ultimately at peace with themselves. What humans can be, they must be. They must be true to their own nature."

There are three other needs discussed by Maslow:

(6) The *desire to know and to understand* is introduced in the first discussion of the theory of needs (Maslow, 1943b), just to indicate that these needs can be partly explained as matters of safety but there is something more: at

least some of us feel the urge to know more and more. We shall return to the discussion of this topic several paragraphs later.

(7) The *aesthetical needs* were only later included in Maslow's ([1954](#)) model, as there is even less known about these than about other needs. However, there is a clinical record that at least some people have truly basic aesthetic needs; they get sick from ugliness and get cured by beautiful surroundings.

(8) The *transcendence* appears in even later work of Maslow ([1971](#), pp. 259-269); he lists 35 meanings of transcendence; his investigation shows that it appears in self-actualizing people.

These last three needs are originally discussed separately from the hierarchy of basic needs but they are today usually pictured in form of eight-layer pyramid (Figure 15), even though Maslow himself had never actually drawn it (at least in none of the numerous papers and books examined).

Source: http://chiron.valdosta.edu/whuitt/col/regsys/maslow.html
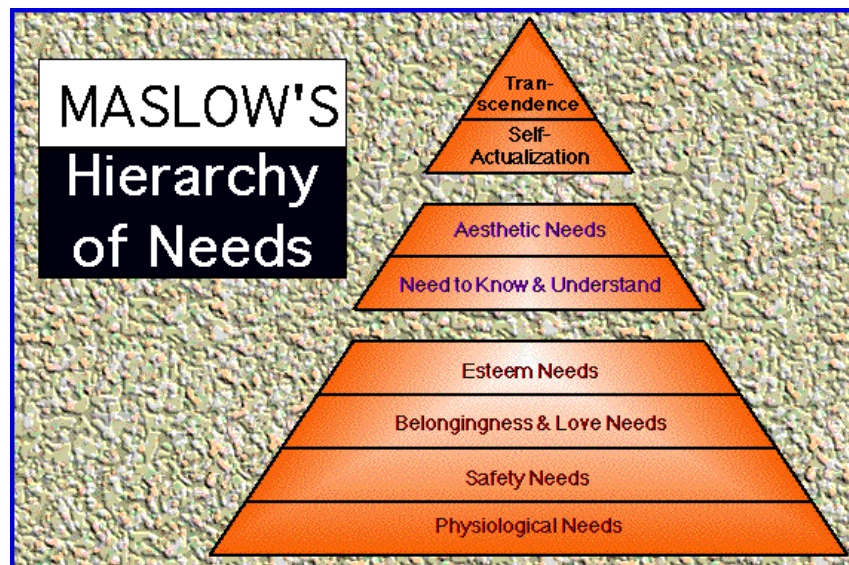
Figure 15: Maslow's hierarchy of needs.

To be faithful to the process of the investigation a private experience will be described here as it was essential for the understanding of Maslow's model as it is presented here. It happened years ago, and remembering it, i.e. the sudden realization that motivation is a factor (more precisely a group of factors) of attention, was the trigger to include the motivation into the MA.

> *I was working on a new course-book with my mentor Zoltán Baracskai, a task that delighted me. After a couple of days of this work I was distracted and produced almost no result. All the sudden, my mentor asked me how much money I needed. I was surprised. I really had some cash flow troubles but I had never told him about them. How did he know? He lent me some £200, a sum that would certainly not get me out of any serious trouble but it was enough. I continued my work enthusiastically and successfully. Later, when we were discussing this topic, he told me that he simply reasoned according to Maslow. I did not want to believe: "… but Spinoza had written such beautiful things and died of hunger, and there were numerous similar examples!" The answer surprised me: "Yes, but he did not write those beautiful things when he was hungry." I was taught on my MBA course that Maslow was wrong and it was explained using Alderfer's (1969) ERG model. I had obviously believed.*

Later, it was discovered that this misinterpretation of Maslow is very common in the management literature. (e.g. Bateman-Snell, 2002, pp. 419-420) We need to examine the difference between the two models closer. Alderfer (1969) distinguished three groups of needs: the existence, the relatedness, and the growth needs. These are very similar to the categories coined by Maslow; the difference is in their interrelations. Alderfer said that if one factor is suppressed for some reason, the other can increase (a common example used in management courses is the student with no security pursuing knowledge). Actually, Maslow had never said that a higher need would not appear before the lower one was satisfied. On the contrary, he spoke of *"hierarchy of prepotency"* and the *"degree of relative satisfaction"*. In the earliest presentation of his model (Maslow, 1943b) he stated explicitly:

"In actual fact, most members of our society who are normal are partially satisfied in all their basic needs and partially unsatisfied in all basic needs at the same time."

He also suggested that the degree of satisfaction of a lower need will determine the degree of emergence of a higher need. He described this phenomenon in the following way (Maslow, 1943b):

"For instance, if I may assign arbitrary figures for the sake of illustration… if prepotent need A is satisfied only 10 percent, then need B may not be visible at all. However, as this need A becomes satisfied 25 percent, need B may emerge 5 percent, as need A becomes satisfied 75 percent, need B may emerge 50 percent, and so on."

He also admitted that the hierarchy is not rigid, the basic needs are not in strictly fixed order, e.g. in some people esteem seems to be more important than love. However, it is still not explained how a certain need is sometimes greater than other times. This last contradiction can be resolved if we realize that needs are what we perceive as needs; and it has sometimes little to do with impartial measures like water content of blood or its hydrogen-ion level. The same can be done more elegantly by applying Russell's (1948, p. 100) egocentric particulars:

"The four fundamental words of this sort are «I», «this», «here» and «now»."

So closer examination has shown us that the two models, i.e. Maslow's and Alderfer's are not contradictory; there is only a shift in emphasis. The first part of the misinterpretation needed nothing else than to really read Maslow's own words and the second part was easily resolved by introducing Russell's egocentric particulars, that is, the subjectivity.

There is another model developed by Maslow (1968), which may help us to deepen our understanding of the nature of needs. In this second model the needs are grouped by their satisfaction:

(1) The needs in the first group are called deficiency needs or *D-needs*; as they work only when unsatisfied, once gratified they are virtually nonexistent. The physiological and safety needs clearly belong here as well as part of love and esteem needs from the original five-level hierarchy; and also the part of the need to know and understand, which concerns safety and the part of aesthetic needs which concerns those getting sick from ugliness.

(2) The being needs or *B-needs* work very differently from the previous group. They cannot be gratified, they are constant drives; we want more and more

of them. Here belong all the needs left out previously; Maslow usually associates them with self-actualization.

For this dissertation the needs will be grouped somewhat differently than presented so far; this involves no changes of their content but only makes it possible to have more details where it is more relevant and less where it is less relevant:[1]

- The D-needs, which correspond to Alderfer's existence, can remain in a single group. They are usually fairly satisfied in individuals that the dissertation is concerned with (see Chapter 6.4 for more details); this will be called the biological level.

- The B-realm of the belongingness and the esteem needs will be considered together as a social level, which also corresponds to Alderfer's relatedness.

- Unlike the previous two, the need to know and understand and the aesthetical needs remain separately as they are of particular importance for knowledge increase; and the self-actualization will be considered inclusive of the transcendence.

Now we have the structure of motivation how it will be used later in the MA in Section 6.4. In this dissertation the social level, as defined above, will be described with love only. Although this is clearly a limitation, and it is somewhat arbitrarily introduced, it had to be done as it would need a complete dissertation to perform a thorough investigation of this topic. There are two other factors that should be considered, namely the economical and the political; however, they would need foundations in economics, sociology and political sciences – this could not be covered in this dissertation. Therefore it is indicated as an area for further research, as it is acknowledged in the Conclusions.

The following discussion of love is a bit of diversion as it appears unconnected to the motivation or to anything else in the dissertation. However, it will be shown to be of crucial importance for the MA in Section 6.4. The real importance of including

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[1] *The explanation for this is better situated in Section 6.4 on modelling MA.*

love into description is that this way the social level of motivation is included (as it is described here with love only, if love is not included it would have not been described). The source of idea for including love to describe the social level was private (i.e. entertainment) reading.

> *I read a book about two year ago, in which, on his pilgrimage to San Tiago, Coelho[1] learned that there are three words for love in Greek: Philos, Eros and Agape. A couple of weeks later I met a Swedish man on a conference in Oxford, who has a Greek wife; he confirmed it and added that e.g. in Swedish there is only one word for love, thus, for example, you cannot say to your children that you love them.*

Fromm (1957) investigated the role of love in our life. He explained that essentially love is a capability of person, not something that happens to her/him (p. 36):

"Love is not primarily a relationship to a specific person; it is an attitude, an orientation of character which determines the relatedness of a person to the world as a whole, not towards one «object» of love."

Fromm identifies five objects of love and five types of love accordingly: brotherly love, motherly love, erotic love, self-love and love of God. The forthcoming categorization largely follows Fromm's description but Lewis's (1960) inquiry is also considered; he presents similar forms of love by mixing types: Need-love, Gift-love, and Appreciative love.

Brotherly love is *Philos*. It is the most essential type of love; the other types of love do not exist without the brotherly love. It is our sense of responsibility and care, our curiosity to know other people, our respect towards others. Brotherly love is love between equals, which does not mean that we are the same but that we are one. Brotherly love also lacks exclusiveness. Actually, two is not even the best number for it. We can understand this better using Lewis's (p. 74) example of friendship, which is the culmination of Philos. If *A*, *B*, and *C* are friends, and *A* dies *C* does not

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[1] *Coelho, Paulo (1997) The Pilgrimage, Harper Collins, London.*

only lose *A* but also *A*'s part in *B*; e.g. how *B* used to laugh on *A*'s jokes. Self-love also belongs to Philos. Self-love emerges from emotional maturity: we cannot love others without loving ourselves, as Fromm (ibid, p. 46) said:

> *"There is no concept of man in which I myself am not included."*

Actually self-love defines the brotherly love: *"love thy neighbour as thyself"*.

Eros or erotic love is much more than sexuality; sexuality, or *Venus* as Lewis (p. 111) calls it, belongs to physiological needs (Maslow, 1954). All kinds of love make us become one with other people but the total union is the erotic love. This is a total fusion with another person. But we are not capable of total fusion with all the other people, thus the erotic love is exclusive; it is a union with a single other person. The phenomenon of oneness and individuality that we can see on personal plain is repeated in erotic love – one loves all the people but loves someone in a special, individual way. Eros, like Philos is love of equals. If in Eros there is no Philos it is only passion. The culmination of Eros is when our partner is our friend too.

If love governs us towards unity with other people, than *Agape*, the love of God, governs us to embrace the whole nature, the whole universe. Coelho (ibid, p. 83) calls it *"love that consumes"*. He gives two examples where he says it can be observed in its purest form: one is a hermit, who leaves the world of people to be consumed by this love and united with everything; the other is the enthusiasm of a person doing… well, doing anything. This second is the same as the flow experience of Csíkszentmihályi (2002) or peak-experience of Maslow (1970) described later on in this section in more details. In Lewis's (ibid, p. 169) description this corresponds to Divine love's manifestation in humans, in particular to Divine version of Appreciative love.

Motherly love, there is also a Greek word for it: *Storge* (Lewis, ibid, p. 39), is not included in the description of the social level. It seems to be somehow a mixture of the previous ones; it is unconditional as Philos, exclusive as Eros and non-equal as Agape. On the other hand it also seems to be a kind of D-love; thus it can be considered to be part of the biological level. Lewis (p. 40) gives similar explanation:

"There is a paradox. It is a Need-love but what it needs is to give. It is a Gift-love but it needs to be needed."

What was discussed so far covers the needed background preparation for the motivational factors of the MA. Next we examine the background of the other group of factors of attention, namely the cognitive factors of the MA. The reason to include these two into a single section is, as we shall see in the forthcoming paragraphs, that the two topics are related. As was indicated, the agapean love is strongly related to the self-actualization as well as to the phenomenon called *"peak experience"* by Maslow (1970) and *"flow experience"* by Csíkszentmihályi (op.cit.). The following discussion will be predominantly based on Csíkszentmihályi's train of thought, but for the beginning a detailed explanation is quoted from Maslow (1971, p. 101):

"The term peak experiences is a generalization for the best moments of the human being, for the happiest moments of life, for experiences of ecstasy, rapture, bliss, of the greatest joy. I found that such experiences came from profound aesthetic experiences such as creative ecstasies, moments of mature love, perfect sexual experiences, parental love, experiences of natural childbirth, and many others. I use the one term – peak experiences – as a kind of generalized and abstract concept because I discovered that all of these ecstatic experiences had some characteristics in common. Indeed, I found that it was possible to make a generalized, abstract schema or model which could describe their common characteristics. The word enables me to speak of all or any of these experiences in the same moment."

Csíkszentmihályi (op. cit. p. 71) portrayed the flow experience in activities (such as work) as a state in which:

"Concentration is so intense that there is no attention left over to think about anything irrelevant, or to worry about problems."

The flow experience can be described as a harmony of knowledge and expectations[1] in narrow flow channel between boredom and anxiety. (See Figure 16) In his own words (Goleman, 1986, pp. 91-92):

"People seem to concentrate the best when demands on them are a bit greater than usual, and they are able to give more than usual. If there is too little demand on them, people are bored. If there is too much for them to handle, they get anxious. Flow occurs in that delicate zone between boredom and anxiety."

There is an additional important point we can note in this comment: the demand should be a bit greater. This makes the flow model perfectly fitting the inquiry into knowledge increase: the demand, which is "a bit greater" enables us to learn something new during our activity; this feature of the model will be used in the MA. For the same reason Goleman (1996) suggests a new model for education which would aim at flow experience; and Baracskai (1999) draws an ironic conclusion that everything can become boring if we are docile.
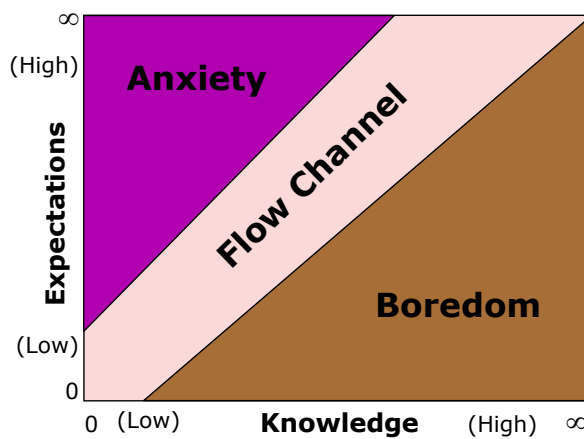
Source: Adapted from Csíkszentmihályi (2002, p. 74)

Figure 16: The Flow experience.

The knowledge increase described so actually makes the difference between the challenge and the anxiety in work. As lecturers we can also frequently experience that the best performance is often preceded by something like stage-fright in actors.

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[1] *In Csíkszentmihályi's terminology: skills and challenges.*

This is nothing like anxiety but more like some state of excitement of doing some-thing interesting,[1] People in business life usually talk about it as a challenging job.

In this section two related topics were discussed: the motivational and the cogni-tive aspects of paying attention, as they will be used in Section 6.4. The first one will be a combination of the restructured version of Maslow's hierarchy of needs com-bined with the different categories of love. The second one will be based on Csík-szentmihályi's model of flow experience, which will first be re-interpreted using the concept of cognitive schemata.

3.7. Expert Systems

> *"... It is irrelevant if the automaton was made of flesh and blood or wood and steel if it could accomplish everything that an intelligent creature could. In this case its mind should be equipped with knowledge, de-cision capacity, and experience. I do not think this should be a problem as I could transfer into it my own intelligence and interpretation."*
>
> *Nikola Tesla[2]*

The last field to touch upon is the field of expert systems (ES). The reason for in-cluding this topic is that in the second stage of the modelling (Chapter 7) a software tool, Doctus (Doctus website, n.d.), is used for simulation/testing with aim to refine the ideas/hypotheses of this dissertation; and thus some understanding of Doctus is essential. There are several classifications provided in this section to facilitate posi-tioning Doctus. The first is to distinguish between the two main paradigms of artifi-cial intelligence (AI), namely the 'strong AI' and the 'weak AI'; Doctus belongs to weak AI. In the next step the examination is narrowed down to the field of expert systems (ESs belong to weak AI), to explain the basic characteristics of the three ma-jor representations of ES, namely the symbolic logic (SL), the neural networks (NN), and the fuzzy logic (FL); regarding these Doctus is an expert system featuring sym-

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[1] *This excitement shows some similarity to sexual excitement, as reported by numerous per-formance-artists.*

[2] *Milinković, Aleksandar (2000): Tesla – pronalazač za treći milenijum (Tesla – inventor for the third millennium). GIP "Karupović", Beograd (Yugoslavia), p. 23.*

bolic logic. Then there is further narrowing of the area of examination to discuss the two basic ways of using expert systems based on SL, namely the rule-based reasoning (RBR) and the case-based reasoning (CBR); Doctus can be used in both of these ways but in this research only the RBR is used and the rationale for this is provided in Section 7.1.

By gradually narrowing the field of investigation we can position Doctus and the way in which it was used in this research; so we can answer the question what is Doctus. There is additional explanation provided in Section 7.1 about how Doctus is used for simulation/testing. There is one more question to answer: why Doctus? The first part of the answer comes for the forthcoming argument of this section, which aims to show that Doctus is appropriate for the job. But, of course, there are other software tools that are appropriate; so why Doctus and not some other package? The other part of the answer is very personal: I know Doctus very well as I have been using it for eight years and for six years I have been a member of the developing team.

The investigators in the field of AI form two paradigms, which differ from each other in their claims regarding what do/can we expect from the created machine:[1]

(1) According to the supporters of strong AI, sooner or later it will be possible to create a machine equal to human. It would behave like a human; it would have human abilities and human mode (e.g. they would think in the same way as humans do). This means that it would even think like a human. (Minsky, 1982) This kind of machine should awaken to self-consciousness, to have intentions, emotions and sensitivity as well. Simon (1977, p. 6) believed even in creativity of machine:

"I believe that in our time computers will be able to perform any cognitive task that a person can perform. I believe that computers already can read, think, learn, create…"

(2) The supporters of weak AI would be satisfied with less. They would like to obtain useful tools, be able to achieve approximate human performance in

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[1] *The metaphor of machines means both hardware and software throughout this dissertation if not indicated differently.*

a particular (narrow) field, but not necessarily in human mode. For this Baracskai said (on various lectures) that a car is not an artificial horse, still it does the job in a narrow field – it takes us where we want. It is also much more comfortable.

These two conceptions are based on different beliefs. Strong AI is based on the belief that human thinking can be known and reproduced. For this the human physical and physiological self has to be primary to thinking. Even if the supporters of the weak AI do not believe (or they do not admit it) in primacy of thought, they are positive that the human thinking cannot be recognized in its entirety; i.e. this is true not only for thinking but also the whole and all cognitive processes (see Section 3.4). On this basis Penrose (1995, p. 12) distinguishes not two but four paradigms, the first of which is roughly the same as the strong AI and the other three are levels of the weak AI. There is no way (at least for now) for one party or another to prove being right; currently the two streams work together successfully, developing the same tools, although from different standpoints. But in parallel with this, a heated debate is going on between the two (or four) paradigms, both parties trying to convince, if not each other, at least those not taking sides; this is not unusual when it is about beliefs. The forthcoming paragraphs give a grasp of some of the major arguments.

The first test concerning the thinking of a machine was suggested by Alan Turing. (1950) The essence was if one is able to decide on whether one is having a dialogue with a fellow man or to a machine based on their answer to questions asked. If a person cannot realize whether the communicating partner is a machine or a human, the machine is (artificially) intelligent. Machines are already built satisfying this expectation (under limited conditions). However, it can be argued that this is not because the machine is thinking. Roszak (1994, p. 131) warns:

"The prospect of machine interpretation is not only whimsical; it is absurd. Interpretation belongs solely to a living mind in exactly the same way that birth belongs solely to a living body. Disconnected from a mind, «interpretation» becomes what «birth» becomes when it does not refer to a body: a metaphor."

A human, who listens to (or reads) the machine's message, can bring sense into a meaningless hotchpotch too. It would be more interesting to invite two computers to chat to each other! If neither one can bring sense into the other's messages, they both fail![1] Searle's ([1998](#), p. 11) *"Chinese Room Argument"* is based on the same idea, though from a different aspect: Assume a person, who does not speak Chinese, is in a room receiving Chinese symbols, i.e. 'questions'. There is a book of rules regulating what symbols to send back as 'answers' to those outside the room. The person in the room is implementing the rules from the book. The person is the computer speaking Chinese. Even if the book of rules is good enough to deceive those outside the room the person still does not understand any Chinese. So, neither does any computer.

Similarly strong arguments support the strong AI camp. In addition to the previous quotation that computers already think, Simon argues that it may be true that the computers only execute their programs but this does not contradict the previous statement ([op.cit.](#) p. 67):

> *"«But after all,» the skeptic may say, «how can a computer be insightful or creative? It can only do what you program it to do.» This statement – that computers can do only what they are programed to do – is intuitively obvious, indubitably true, and supports none of the implications that are commonly drawn from it."*

Minsky ([2004](#)) reverses the Chinese Room Argument: if we succeed in creating a "zombie machine" which seems to be identical to the human, if it injures a leg and complains about the pain (as it was programmed so), it will behave as a human with a pain in the leg. Can we claim that it does not hurt – that the "zombie machine" does not feel? Further complications would arise if we cannot distinguish the "zombie machine" from a human being; we could reverse the question: can we claim that the human being feels?

The argument so far aimed to give a brief but clear distinction of the two main approaches to AI; to make understandable what it means that Doctus belongs to weak

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[1] *In Rosenhan's ([Slater, 2005](#), pp. 63 ff) experiment, healthy people were sent to a mental hospital, to fake mental illness; the psychiatrists did not discover the deception; however, the patients did – they excommunicated the ones not belonging amongst them.*

AI. From this point onwards, the focus is on the computer programs realized in AI, called expert systems, to get a step closer to Doctus. Expert systems are not new tools but they are probably the best working, results of the AI research, as suggested by Herbert Grosch (quoted in Roszak, op. cit., p. 124):

"The emperor – whether talking about the fifth generation or AI – is stark naked from the ankles up. From the ankles down, the emperor is wearing a well-worn and heavily gilded pair of shoes called expert systems. They are useful, but we've had them for over thirty years. All that the fifth generation boys have done is relabel them."

The quotation aimed to enhance trust in expert systems. But what expert systems are? The term 'expert systems' carries a twofold message: they are expected to give performance on the level of a human expert, and they are expected to provide this performance in a narrow domain. There is another term often associated with expert systems, knowledge-based systems (KBS), indicating that these software packages use knowledge bases. Although sometimes KBS are identified with ES, they are not the same: not all expert systems use knowledge bases, as it will be described in the next paragraphs.

There are two mainstreams of knowledge representations in expert systems: the symbolist and the connectionist. (Minsky, 1990)[1] The essence of the symbolist conception (or Symbolic Logic – SL) is to store knowledge in a knowledge-base (so, these are KBSs), its elements are symbols which are connected by logical rules in «if… then» form. The connectionist conception emphasizes functioning on sub-symbolic level. This means transforming symbols into numbers and then performing calculations instead of using logical rules. Two important realizations of connectionist conception are neural networks (NN) and fuzzy-logic (FL). Genetic algorithms

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[1] *It is an interesting fact that first the symbolic representation dispersed widely, even though the first realised AI was a neural network – the doctoral thesis of Marvin Minsky, the AI guru. (Russell-Norvig, 2002, pp. 16-17)*

(GA) are often also ranked with connectionist conception,[1] since the important feature of GA is fitness, which is given in the form of calculable functions. Nothing prevents us from creating a logical fitness-function. This way the GA may show up in symbolists' toolbar as well as in connectionists'. The GAs are mentioned only to include the full picture; they are not mentioned further in this dissertation. Now a brief description of the strengths and weaknesses of SL, NN, and FL follows.

The first advantage of **symbolic logic** is that it does not quantify user's preferences. E.g. the person whose knowledge is being modelled thinks that beautiful is a better value than ugly. Nobody thinks that beautiful is 3.6 times better than ugly. Using symbolic logic we do not state something like that. In the symbolic knowledge-base of an expert system we can express our knowledge in a natural form: as we talk or think. This leads to three additional advantages: transparency, easy modification and fine-tuning of the knowledge base. A disadvantage is that numerical signs can also be treated only as symbols, so if we want to use numerical data, first we have to transform them into symbols. This can be done manually, i.e. instead of reciting numerals, the expert formulates symbols, such as «too much», «not enough», etc. or using a (statistical or Fuzzy) clustering algorithm. So this disadvantage can be eliminated but it means additional work. The second disadvantage is that if there are many symbols, there will be a plenty of rules. Today, this is not problem of computing capacity. The expert-level knowledge means a few thousand rules,[2] which can be easily handled by modern software. However, it is hard to acquire a lot of rules from the expert due to the limit of STM (Section 3.4); the use of multi-step reasoning helps. (See detailed explanation in Section 7.1.) The next disadvantage is that there is no access to the tacit knowledge; there are knowledge elicitation techniques coping with more or less success with retrieving a part of tacit knowledge, but this is out of the scope of this dissertation. Here the research is aimed to result in explicit knowledge.

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[1] *Actually there are four tools in this group: genetic algorithms, genetic programming, evolutionary algorithms and evolutionary programming. The statements in this discussion apply to all of them; therefore there is no need to treat them separately.*

[2] *The explanation is that the expert-level knowledge indicates a few thousand cognitive schemata, as it will be explained in Section 4.1.8; and this corresponds to few thousand rules.*

The successful applications of SL are usually aimed at the identified capacity limit of STM (i.e. several thousand rules can be made available at once), e.g. by providing expert opinion available to the decision taker.

Neural networks (Vellido-Lisboa-Vaughan, 1999) are based on human nervous system in that their architecture resembles the physical structure of the nervous system. There are software-made elements (neurons), dull enough but plenty of them, with complex interconnections (net); the NN is trained on basis of learning samples. NN builders believe that it is only matter of time and advancement in technology to build a network as complex as the human nervous system; and as the elements used in NN are much faster than human nerve-cells, the builders assert that NN will think faster than humans. In NN there are no rules, there is no knowledge-base, only learning samples. NN reproduces the statistical rate of the pattern of features of the learning samples; therefore they require a large number of repetitions and can be used only for stochastic processes, not for heuristic ones (see Section 3.2), where the process of knowledge-increase belongs. Paraphrasing Polányi (1964, p. 43)[1] this may be called non-intelligent imitation of examples. One great strength of NN is that they can replicate motions, in which sample-following prevails; thus it can produce e.g. great robot-pilots. Since the NN learn quickly, they can be also used for speech recognition. In business applications NN are usually used as data mining tools to discover interesting patterns in large databases.

Fuzzy-logic representation uses fuzzy-sets as elements. They differ from conventional sets (crisp sets) in that instead of stating whether something is or is not an element of a set, it uses degrees of memberships indicating to what extent an element belongs to a set. So, in FL the set-boundaries are not rigid; to use the classic example of the Fuzzy literature, the FL handles the "paradox of the pile of sand".[2] (Zadeh, 1992) This is sub-symbolic representation indeed (cf. previously in this section). Zadeh (1965) has originally developed fuzzy-sets for handling concepts that actually

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[1] *"Speech is learned by intelligent imitation of the adult." (See Section 4.2.3 for the whole quotation)*

[2] *How many grains of sand are needed for a pile? If we remove one grain, does the pile stop being a pile? What if we add one more grain? And so on.*

have sub-symbolic level (e.g. cold, very warm, short, fast). A great feature of FL is its capability to make relations between the symbolic and sub-symbolic levels: between quantifiable and un-quantifiable, so between arithmetic and logic. FL needs fewer rules than the symbolic representation due to its sub-symbolic functioning. This is valid for the given number of attributes. However, there is a catch. In a symbolic representation we have e.g. the attribute «clothing» with values «sloppy», «casual», «elegant», «extravagant», and «formal». It would mean five attributes in FL, for each of which we have to define a membership function for all the cases, which makes the design of an FL expert system very time consuming. In case of multi-step reasoning, the Fuzzy-sets 'flatten out'[1] a property which is usually considered to be a disadvantage; however, this makes FL convenient for fast approximation of functions and for creating efficient control loops by providing more nuances of control signals. Since it converts quantitative signs into something less concrete, the FL is easy to use in noisy environments as well as when the result of measuring is imprecise.

Apart from 'pure' representations (i.e. using one of the above mentioned) there are two approaches to joint use of the different representations. We can create *hybrid representations*, i.e. two or all the three of the previous conceptions are combined on a representational level (and GAs can also be used in these combinations). Examples for this are when we put a fuzzy representation as an input to the NN, or when we attempt to extract symbolic rules from NN. (e.g. Zhou-Jiang-Chen, 2001) An interesting joint use of SL and FL is to provide fuzzy-clustering for SL to handle the numerical inputs.[2] Beside of the hybrid representations, we can divide the task *functionally* among the different approaches. As a hypothetical example, consider a robot taking a glass from the table: the NN trains how to take a glass from the table, the FL smoothes the motion process and the SL decides if the glass should be taken or not in the particular situation.

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[1] *I.e. they become un-determined.*

[2] *At one point it was assumed that it would be beneficial to use a fuzzy-clustering for Doctus for this investigation; and thus the conception of an automated fuzzy-clustering was developed. Although this research took another direction and the idea was not included into the dissertation, it has been published as a conference paper. (Baracskai-Dörfler, 2003)*

These were only brief descriptions of the three representations with few examples; as this section only aims to give a rough picture of AI and ES to place Doctus KBS into a frame. Now the area of examination is further narrowed and henceforth only the expert systems, which use SL (as it was said at the beginning of this section, Doctus belongs to this group) are examined.

These ES may store the knowledge acquired from an expert in the form of rule lists, frames or objects (Russell-Norvig, 2002); some are purpose-built, others consist of a pre-programmed shell and a purpose-built knowledge base. Further examination is focused on ES using a shell (as Doctus is a shell) with a knowledge base in form of a rule list. They have two basic modes of use, the deduction, also called Rule-Based Reasoning (RBR) or the induction, also called Case-Based Reasoning (CBR)[1].

In RBR, which is the inference mode used in this dissertation, the expert defines the attributes (decision aspects) and their values (cf. Section 3.1), then organizes the attributes into a multi-step hierarchy and defines the «if… then» logic rules between the attribute values. Cases (alternatives) are described by choosing a value for each input attribute (case features). A knowledge engineer helps the expert to articulate her/his knowledge.[2] RBR has two forms:

(1) In **forward chaining** we get answer for «what if…» question. We can call this a data driven deduction.

(2) In **backward chaining** the question is «what is needed for …» We can call this a goal driven deduction.

In CBR the expert describes the cases, for which she/he chooses attributes and their values. For this we need cases that have already occurred, so that the outcome

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[1] *Originally the case-based reasoning was inherited from quantitative decision support and is usually used in the connectionist approach. (Gupta-Kalyan-Montazemi,1997) Its essence was – and often it still peeps out behind the veil of symbolic solution – to define some metrics and distance built on it, which will be the similarity. For a new case the nearest one – that means the most similar one – is searched from the case-base. In symbolic logic, cases described with the same rules are considered to be similar.*

[2] *We call this process knowledge acquisition; it is part of a wider process called knowledge engineering. Knowledge engineering besides knowledge acquisition contains fine-tuning of the knowledge-base and the explanations of the results. (Velencei, 1998)*

(the value of the benchmark attribute) can also be described. During the process of knowledge acquisition and knowledge engineering the knowledge engineer assists the expert, as previously in RBR. The software induces the rules on basis of the cases of the expert's experience. The output is in a form of a decision tree or a rule list – which are equivalent to each other. As in this research RBR was used, here no further details are provided about CBR, the two basic algorithms of this kind of reasoning can be found in Appendix 3 and Appendix 4; a rationale for adopting RBR rather than CBR is given in Section 7.1.

Now what was said at the beginning of this section makes sense: Doctus belongs to weak AI, it is an expert system, it uses symbolic logic, and it is also a KBS shell. Doctus is capable of RBR, doing forward chaining in a traditional way, while the backward chaining is supported with an explanatory option[1]. It is also capable of CBR, using modified C4.5 algorithm[2] and displays the result in the form of a case-based graph. From the case-based graph Doctus generates a single-level deductive knowledge base using reduction, in which only the informative attributes appear. Explanation of the use of Doctus comes in Section 7.1.

This section introduced Doctus by positioning it in context of expert systems and in broader context of artificial intelligence, with aim to give a large-scale picture about the tool which was an important tool for this research. The Doctus shell is used in this dissertation directly as the tool to develop the simulative models in Chapter 7 for fine-tuning the ideas/hypotheses. It was also used indirectly throughout the investigation for the clarification of the complex thinking processes used in the research: when constructing a knowledge base the user is forced to formalize her/his thinking to some extent, which helps clarifying the arguments. Finally, when it was not used at all, Doctus still influenced the way of thinking as a part of the background knowledge. This gives an idea of how important Doctus was in the present research. More detailed introduction about RBR in Doctus – this is used for the modelling – is given through hands-on explanation of usage in Section 7.1.

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[1] *The user may ask why a particular value appeared in the evaluation and the «Explain» will take her/him to the rule which was applied.*

[2] *C4.5 is an enhanced version of the ID3 algorithm (Quinlan, 1993).*

3.8. Chapter Summary

This is the end of a rather eclectic and very long chapter (covering the second-top layer of Figure 3). The chapter contains several new results which do not belong to the mainstream of the research; some of these have already been published, others are too small to make for a full paper alone, again others are beginnings of new research directions. These will all be revisited in the Conclusions.

What was discussed in the first two sections will not explicitly appear in the final models; however, the presented ideas tacitly influenced the process of modelling. The distinction of the roles of management and leadership in relation to knowledge in organizational contexts is the basis for the idea of knowledge modelling that is used in the present research, for both the descriptive and the simulative stage. The integration of the bounded and the intuitive rationality is an original contribution of this research; and this rationality of decision taker is underlying the MLW in which the individual decides whether to accept the new knowledge or not.

The other six sections dealt with preparing issues that will explicitly be used in one or more of the forthcoming parts, namely in closer examination of knowledge, in descriptive and/or in simulative modelling. The systems as described here are relevant as a thinking mode about the result of the dissertation, which can be regarded as a system, and also the knowledge is considered as a system and is described as such. An original contribution here is the description of the processes of different complexity. The value systems are introduced here as the MLW is describing the interaction of the individual and the organizational value systems in which the decision of the individual about the new knowledge is taken. Cognitive processes are described to prepare the understanding of the new concepts that are used for describing the system of knowledge and the process of knowledge increase. Attention is relevant for the MA; this section also contains an original contribution, namely the two exercises used for refining the existing models of attention – nevertheless this result is not enough for a publication. One section was devoted to the related topics of motivation and flow experience. First, Maslow's original model was described contrasting it to the mistaken interpretations; then this model was restructured to fit the need of mod-

elling the motivational factors of attention. Then a bit of diversion was committed, by describing love – the role of which is probably less clear than for the other parts; this description will be used to describe the social level of motivation in the MA. The flow experience is described here in a simplified form but following Csíkszentmihályi's original model; later it will be restructured so that it can be used to describe the cognitive factors of attention but for the restructuring some additional concepts are needed. Finally the introduction of expert systems with the first section forms the framework of the chapter. This introduction starts from the general description of AI, gradually narrowing the area to the expert systems and to Doctus in particular which is used to create the simulative models. The seven years' work with Doctus including nearly dozen previous conference papers and around a hundred business implementations was certainly used tacitly in the section. Further details about Doctus will be given in Section 7.1.

These sections all gave an introduction to some of the neighbour disciplines which are used as tools, conceptions, beliefs, models, approaches, etc. during the forthcoming examination of knowledge in the next chapter or in the modelling stage in Chapters 6 and 7. Now the area of research can be narrowed to examine the knowledge and the knowledge increase, which is done in the next chapter.

4. Defining the Component Problems

Having introduced the mental framework adopted for the dissertation in Chapter 2 and the problem domain in Chapter 3 in the present chapter, which corresponds to the third cycle of the spiral of discussion (Appendix 2), the inquiry can be further narrowed to knowledge and knowledge increase.

In this dissertation knowledge is presented as a system, and knowledge increase is modelled as a process in this system. First a model of knowledge as system is constructed, then some features of it and processes in it are examined to refine it. Henceforth this model will be referred to as the *preliminary model* as it serves as basis for the four models: the Model of Learning Willingness (Section 6.2), the Model of Learning Capability (Section 6.3), the Model of Attention (Section 6.4), and the Model of learning Ability (Section 6.5); which are the results of this research. The purpose of the preliminary model and its examination from various aspects is to provide better understanding of the process of knowledge increase, which is the overall purpose of this investigation.

The choice to model knowledge as a system and the knowledge increase as a process within this system is arbitrary on one hand; on the other hand as it was said in Section 3.2 we can actually consider anything to be a system as long as we do not forget that the system is not the description of the reality itself but of our knowledge of that reality. With hindsight it can be judged a fruitful attempt to modelling.

This chapter is divided into three subchapters (second level titles); the sections (third level titles) within the first two unfold in parallel, examining the knowledge and the knowledge increase along the same aspects. Subchapter 4.3 is a kind of chapter summary but it is not a simple repetition of what has previously been said; it is also a synthesis of the findings from the examination aspects, to establish the dimensions of the examination done in Chapters 6 and 7. There will be three such dimensions corresponding to MLW, MLC, and MA respectively. The preliminary model will be described using mathematical symbolism at the beginning of Chapter 6.

4.1. Knowledge

"In saying that a conscious being knows something, we are saying not only that he knows it, but that he knows that he knows it, and that he knows that he knows that he knows it, and so on…"

John Randolph Lucas R.[1]

The purpose of this subchapter is to introduce the first part of the preliminary model, i.e. the knowledge as system, and to examine it along some aspects. The aspects chosen here do not cover everything that could be said about knowledge (how could they?), only what is relevant from the viewpoint of the investigation.

The subchapter is divided into nine sections; the first gives an overview of the definitions of knowledge from literature, and the other eight discuss the aspects of the investigation. The first one explains the elements of the knowledge as a system, the second describes the personal nature of knowledge, the following five are various knowledge typologies, and one section discusses the value of knowledge from the viewpoint of both the individual and the organization.

This subchapter goes – and can be also read – in parallel with the next one; i.e. the sections of this subchapter correspond to the sections of the next one. Most of the content of this subchapter is taken from literature and some are based on observations made during the present research.

4.1.1. Definitions of Knowledge

Strict definition of knowledge in the sense of Section 2.7 is rather an unpromising enterprise. It will be shown in this section that even the most important authors in the field abandoned this attempt and have either given up the definition entirely or been satisfied with indicating several features of knowledge important from their aspect at the time or giving a metaphor also valid for a single quest only. This is accepted as a valid argument against the strict definition of knowledge; and so the knowledge will only be described with several metaphors in this dissertation.

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[1] *Lucas, John R. (1961) Minds, Machines and Gödel, Philosophy, 36, 112-127. Online version: http://users.ox.ac.uk/~jrlucas/mmg.html (accessed 09/10/2005)*

The first knowledge definition often referred to in literature is that of the justified true belief – JTB (e.g. Nonaka-Takeuchi, 1995, p. 58 and Takeuchi, 1998), and it is attributed to Plato (360 BC). The conception of JTB indeed appears in discussion of Socrates with Theaetetus and Theodorus but, at the end they give up upon it. The discussion is worth taking a closer look. They start from a working hypothesis that, according to Protagoras' doctrine "*Man is measure of all things*", knowledge is perception but only to realize that senses can deceive, so knowledge should be an interpreted perception, furthermore, it cannot be the perception of just anybody. Thus they suggest modifying the previous doctrine as not all men but only wise men are the measures of all things. So knowledge is, for a moment, defined as reasoning about impressions of senses (and direct sensations of mind, e.g. odd or even numbers) considering past, present, future sensations about being and the use of them. Rephrasing this, knowledge becomes defined as opinion, and, after a short discussion, a further restriction is made: not all opinion, only true opinion. However, as usual, Socrates found a counter example: in the law court a judge may have a true opinion if the suspect is guilty or not but he has no knowledge of it. This leads to the conception of JTB:

"true opinion, combined with definition or rational explanation, is knowledge".

Here, just before the end of the dialogue, comes the most surprising turn, Socrates and Theaetetus show that the *"definition or rational explanation"*, that is the justification, is impossible without presupposing knowledge, i.e. knowledge of the differentia specifica (cf. Section 2.7); and, what rarely happens in Plato's works, we are left without solution, i.e. without definition for knowledge.

So, even if knowledge cannot strictly be defined as JTB, nearly two millennia later Gettier (1963) asked a question: does this approach provide us with necessary and sufficient conditions for knowing? He also answered it: no, by providing two examples when the three conditions (i.e. that the proposition is true, that the subject believes in it and she/he is justified in this belief) are not sufficient. Both examples are constructed to show that one may be justified in a true belief but still not know it. In both cases inference is used from one proposition to another, the original becomes false but by coincidence the second proposition is true. Of course the examples are

constructed ones but what can be constructed can also actually happen. And we have all seen more than few such examples. In the following four decades there were significant efforts made to find the 'fourth condition' but with no result. Recently Floridi (2004) has shown that the Gettier problem is demonstrably insolvable, which means that the three conditions may be necessary but they are certainly not sufficient. This hopefully puts an end to the two millennia long debate on JTB. It is worth noting that the whole JTB-conception only refers to the kind of knowledge that is expressible in the form of propositions and as it will be discussed in the forthcoming sections of this chapter it is only a small part of what we can consider as knowledge.

Russell (1948) spent most of the 518 pages establishing what knowledge is not; to leave us at the end with the following instead of a definition:

"... all human knowledge is uncertain, inexact, and partial. To this doctrine we have not found any limitation whatever."

For Polányi (1962a) we can either say that he did not define knowledge at all or that he gave us a 403 page long definition. He described important features of knowledge and created a series of models of knowledge according to various typologies.

Nonaka and Takeuchi (1995, p. 58) adopted the JTB conception, although they use it with significant shifts in emphasise replacing 'truth' with 'belief in truth'. They also list features of knowledge important for their approach:

"First, knowledge, unlike information, is about beliefs and commitment. Knowledge is a function of a particular stance, perspective, or intention. Second, knowledge, unlike information, is about action. It is always knowledge «to some end». And third, knowledge, like information, is about meaning. It is context-specific and relational."

Davenport and Prusak (2000, p. 5) do not 'pretend to provide a definitive account' themselves, rather they try to express what makes knowledge valuable and to describe some characteristics of it:

"Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms."

Sveiby (1997, p. 37) provides a metaphor and some descriptive explanation:

"... for the purposes of this book I define knowledge as a capacity to act. This is not an all-encompassing definition but rather a practical notion for managers to keep in mind as they read the rest of the book. One's capacity to act is created continuously by a process-of-knowing. In other words, it is contextual. Knowledge cannot be separated from its context... The «act» in the definition can be a practical one, like chopping wood and walking, or an intellectual one, like speaking and analyzing. In this book the dynamic and active properties of knowledge are emphasized, so the terms knowledge, competence, and process-of-knowing are all used."

All in all, there seem to be no definition available in literature that we could call a definition. Maybe these two and half millennia of inquiry into what knowledge is that we have recorded are too short period for such enterprise. Or, it may well be that knowledge is not something that can be defined at all. Whichever is the right answer, this dissertation does not engage in trying to fabricate a definition, rather it will use some metaphors and typologies to gain understanding without a clear-cut definition, as it is done throughout the sections of the present chapter.

4.1.2.   Aspect 1: System of Knowledge

As knowledge is modelled as system in this dissertation, its elements are to be defined; the elements of knowledge as system, for this dissertation, are the ***cognitive schemata***. The elements, the interrelations between them, and their structures, including the subsystems are examined. The features of the knowledge are explained through the behaviour of the system. This model is developed by applying a systems approach to cognitive psychology; the system is of level 7 (Section 3.2).

The concept of ***cognitive schemata***, in the meaning as used here, was developed by Bartlett ([1932](#), p. 199 ff), although he mentioned that the term *"schemata"* was already in use – in fact, this was the reason why he said (pp. 200-201):

"I strongly dislike the term «schema». It is at once too definite and too sketchy… it does not indicate what is very essential to the whole notion, that the organised mass results of past changes of position and posture actively doing something all the time; are, so to speak, carried along with us, complete, through developing, from moment to moment."

The trouble with schemata is that, similar to knowledge, we do not really know what they are. They are the basic units of knowledge – as we have defined them so. As Neisser ([1967](#), p. 8) said:

"… in the eyes of many psychologists, a theory which dealt with cognitive transformations, memory schemata, and the like was not about anything. One could understand theories that dealt with overt movements, or with physiology; one could even understand (and deplore) theories which dealt with the content of consciousness; but what kind of a thing is a schema? If memory consists of transformations, what is transformed? So long as cognitive psychology literally did not know what it was talking about, there was always a danger that it was talking about nothing at all. This is no longer a serious risk. Information is what is transformed, and the structured pattern of its transformations is what we want to understand."

Although, Neisser's interpretation might be right, it does not help the present investigation; the unknown term was only replaced with another unknown one. The trouble with the information is that people (would) like to measure it. This measurement is often based on the Shannon-formula ([Shannon-Weaver, 1963](#), p. 14), which is appropriate for measuring – measuring the capacity of the communication channel. However, it has nothing to do with the information. A variety of mutually incompatible definitions is available for the information depending on the discipline and the taste of the author. Usually the definitions assume some kind of new data input; it is a reasonable question if one needs the particular new data. One can get the phone number of a tax specialist, which is new data for one, but one does not need that new

data – so is it information or not? And if one needs the phone number at a later time, does it become information at once? An infinite number of similar questions could be asked. Drótos (2001, p. 10) formulated it really neatly:

"... which measuring unit would be appropriate to express the amount of information in a satellite record, in the flavour of a rose, in the Bolero or e.g. in this hypertext? We do not know the answer to this question, yet, maybe there is no answer to it at all."

To avoid the trouble and misunderstandings about the concept of information in this dissertation the term 'information' will be avoided. Instead, the schema-description of Mérő (1990, p. 84) is adopted:

"Cognitive schemata are units meaningful in themselves with independent meanings. They direct perception and thinking actively, while also being modified themselves, depending on the discovered information. Cognitive schemata have very complex inner structures, various pieces of information are organized in them by different relations. The various schemata are organized in a complex way in our brains; in the course of their activities they pass on information to each other and also modify each other continuously."

A cognitive schema can be anything that is one single whole in our knowledge, a number, a letter, a word or a whole poem. We have demonstrated this to our students countless times. First we ask them if they know the national anthem, and then ask what is the 10th word of it; after several seconds we continue: "So you do not know it after all?" It is important in this demonstration not to ask a word before the 9th and not to wait too long before the conclusion. The national anthem is also a single schema, which is the reason that they cannot respond immediately; first they have to take it apart – this shows that schemata are organized hierarchically. Simon (e.g. Chase-Simon, 1973) calls this phenomenon chunking. The cognitive limit introduced in Section 3.4 can be fully understand now: the limit of 7±2 refers to the number of schemata that can be stored in the STM. Substantial experimental evidence for this limit of STM can be found in Chase and Simon (ibid), Gobet and Simon (1996a and 1996b), and Mérő (ibid).

There are several other terms used for the particulars of knowledge beside cognitive schemata; they have similar meanings. Simon calls them *"chunks"* to emphasize the phenomenon of chunking. Minsky ([1974](#)) calls his conception *"frames"*:

"A frame is a data-structure for representing a stereotyped situation, like being in a certain kind of living room, or going to a child's birthday party. Attached to each frame are several kinds of information. Some of this information is about how to use the frame. Some is about what one can expect to happen next. Some is about what to do if these expectations are not confirmed."

There are also terms of *"units"* and *"scripts"* mentioned by Rumelhart and Norman ([1988](#), p. 536), but they also use the term *"schemata"*. They describe schemata as some kinds of models of reality with the following features: They have variables; can be embedded one into another; represent knowledge at all levels of abstraction; they are more like encyclopaedias than lexicons; they are active recognition devices also evaluating how they fit the situation.

To describe the active participation of schemata in perception and remembering Neisser ([1967](#), p. 94 for perception and p. 285 for remembering) uses Hebb's example comparing the perceiver rememberer to a palaeontologist – we perceive fragments of bones and we see a dinosaur.

All the introduced conceptions agree about the hierarchical structure of schemata; which is not, of course, a static structure.[1] In this dissertation, for easier handling the term of meta-schemata is also introduced, meaning a schema that has another schema embedded; this does not mean that the lower level schema is not a meta-schema itself but this terminology simplifies the description of particular situations. When we complete a task, take a decision, or solve a problem several schemata become organized into an ad-hoc structure. ([Baracskai, 1999](#), pp. 47-51) If working on the task, the decision, or the problem results in a deeper understanding, a ***meta-schema*** is formed,

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[1] *To grasp an image for intuitive understanding, imagine a pail full of medusas. They have really no shape, though that non-shape is constantly changing. If you make your medusas, floating in the material made of their own non-shaped bodies, once to shake their tentacles, once to release their hug, you are on the right way to imagine how the cognitive schemata work.*

and that usually dissolves some of the incorporated schemata but can re-create them on other occasion. This is how a good mathematician, who 'forgot' integrals, can learn it in very short time without any additional input. This means that the meta-schema stores the structure of the incorporated schemata. As knowledge is presented here as system, meta-schemata correspond to subsystems. A particular schema may belong to multiple meta-schemata, and then we say that the meta-schemata overlap. They may also be extended to incorporate an additional schema (or more of them) and they may merge as well.

Further details about the nature of cognitive schemata are discussed in Section 4.1.8 from the viewpoint of knowledge; in Sections 4.2.2 and 4.2.8 from the viewpoint of knowledge increase; the model is described using the symbolic language of mathematics in Section 6.1.

The reason for this circumstantial examination is that the cognitive schemata are not very accessible. We can neither put them under a microscope nor measure their weight or size. The only possibility is the indirect examination, i.e. drawing conclusions about their features on basis of observing their (inter)actions.[1] This can be done only when the schemata are in STM.

4.1.3. Aspect 2: Personal Knowledge

The conception of ***personal knowledge*** is adopted in this dissertation to contrast it to the conception of organizational knowledge, claiming that the latter does not exist in the same manner as the former. In the sense in which it may exist, the organizational knowledge is not investigated in this dissertation. The concept of personal knowledge is originally coined by Polányi ([1962a](#)) and here it is used with the same meaning, although, with a slight shift in emphasis.

According to Polányi's ([1962a](#), p. 17) original definition, the personal knowledge bridges the gap between objectivity and subjectivity, thus it is neither objective nor

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[1] *This is similar to the measuring in quantum physics. We are unable to directly measure the mass of an electron, but we can conclude it by knowing how much (kinetic) energy it transmits in collision.*

subjective. In accordance with what has been said about *qualia* (Section 2.4) we could also say that the knowledge is both objective (as it is about reality) and subjective (as it is someone's knowledge) at the same time. The reason for this difference comes from Polányi's ([ibid](), p. 300) different account for subjectivity:

> *"... I think we may distinguish between the personal in us, which actively enters into our commitments, and our subjective states, in which we merely endure our feelings. This distinction establishes the conception of the personal, which is neither subjective nor objective. In so far as the personal submits to requirements acknowledged by itself as independent of itself, it is not subjective; but in so far as it is an action guided by individual passions, it is not objective either. It transcends the disjunction between subjective and objective."*

The last sentence of the quotation is applicable here too, in the same form.

The term of personal knowledge emphasizes two features of human knowledge. First it is always the knowledge of an individual. As Nordström and Ridderstråle ([2002](), p. 17) have put it:

> *"For better or for worse, knowledge is controlled by the single individual."*

According to Einstein ([1956](), pp. 8-9), even if we *"inherit some knowledge"* from the society it was originated in the mind of an individual:

> *"It is clear that all the valuable things, material, spiritual, and moral, which we receive from society can be traced back through countless generations to certain creative individuals. The use of fire, the cultivation of edible plants, the steam engine – each was discovered by one man. Only the individual can think, and thereby create new values for society – nay, even set up new moral standards to which the life of the community conforms. Without creative, independently thinking and judging personalities the upward development of society is as unthinkable as the development of the individual personality without the nourishing soil of the community."*

This means that the individual is the knower, but the organization, of which the individual is member, affects this knowledge, i.e. the same individual is not the *same*

as member of different organizations. The effect of the organization in this dissertation is taken into account through the individual and organizational value systems and their interactions (see Section 4.1.9).

The second feature emphasized by the term of personal knowledge is that the whole personality of the individual is in constant interaction with her/his knowledge. These two features combined produce consequences important for organizations. You hire a worker and you get a whole person. You offend the person and the worker walks out of the organization taking your most valuable asset – her/his knowledge – with away. Drucker (1999, p. 149) described the knowledge worker in the following way:

"But knowledge workers own the means of production. It is the knowledge between their ears. And it is totally portable and enormous capital asset. Because knowledge workers own their means of production, they are mobile. Manual workers need the job much more then the job needs them. It may still not be true for all knowledge workers that the organization needs them more than they need the organization. But for most of them it is a symbiotic relationship in which they need each other in equal measure."

This dissertation starts from the presumption that there is only personal knowledge, i.e. all knowledge is knowledge of particular individuals. The organizational knowledge may exist in a Jungian (1968) sense of collective consciousness but in that sense it is not investigated in this dissertation. We know, of course, that knowledge is of huge importance to organizations, as Nordström and Ridderstråle (ibid, p. 30) say:

"The critical means of production is small, grey and weights around 1.3 kilograms. It is the human brain."

This importance of knowledge is what puts managers into difficult situations and makes important for them to gain better understanding of personal knowledge (Drucker, 1999, p. 149):

"Management's duty is to preserve the assets of the institution in its care. What does this mean when the knowledge of the individual knowledge worker becomes an asset and, in more and more cases, the main asset of an institution?"

More appropriate terms are available to emphasize the importance of knowledge for organization, e.g. Davenport and Prusak (2000, pp. 12-18) talk about *"knowledge as corporate asset"*, Sveiby (2004) uses two terms *"intangible asset"* and *"intellectual capital"*, Nonaka and Takeuchi (1995, p. 55) refer to *"invisible assets"*. To be sure, these authors also use the term "organizational knowledge" interchangeably with their other terms − so as a metaphor. There is nothing wrong with metaphorical use of organizational knowledge; it is just that we must not forget that it is a metaphor − the knowledge remains in the heads of individuals.

4.1.4.   Aspect 3: Tacit and Explicit Knowledge

In his various works Polányi has developed a series of models about human knowledge. One of the most cited ones, the **tacit-explicit** (the latter is also referred to as codified), is introduced in this section; starting from assertion that (Polányi, 1966, p.4):

"I shall reconsider human knowledge by starting from the fact that we can know more than we can tell. This fact seems obvious enough; but it is not easy to say exactly what it means. Take an example. We know a person's face, and can recognize it among a thousand, indeed among a million. Yet we usually cannot tell how we recognize a face we know. So most of this knowledge cannot be put into words."

It is interesting that Polányi has actually never used the term of *"tacit knowledge"* in his celebrated *"The tacit dimension"*. He used the term of *"tacit knowing"*. A deeper inquiry into this peculiarity can get us to better understanding of knowledge; this will be shown through a personal story in the next Section as another model of Polányi has to be introduced first. For now it is enough to realize that **knowledge** is a state of mind and **knowing** is an act in which knowledge is used.

For the full picture it should be said that Nickols (2000) added a third category to this model, the implicit knowledge, which is a tacit knowledge that can be made explicit. We cannot know ex ante which part of the tacit knowledge can be made explicit, only ex post, i.e. once it became explicit. Thus this third category is abandoned in the present research, although, it is important to note that there is a bidirectional transfer between the tacit and the explicit domain. For instance, when we learn a grammatical rule in a foreign language, we can put it into words – so it is explicit; later we forget the rule (we cannot articulate it anymore) but we still use it perfectly when writing – so it became tacit. An example for the opposite direction can be when the knowledge engineer helps the expert to put a part of her/his tacit knowledge into words, the result is usually surprising for the expert, thus the phenomenon is called knowledge discovery.

Mustering up a number of experiments (face-recognition, expecting an electric shock looking at senseless syllables, using a probe to explore a cavern, the use of a stick by a blind, unawareness of particular muscles during a movement, use of tools), Polányi (ibid, pp. 7-19) defines the structure of the tacit knowing borrowing metaphors from anatomy. It is defined by two terms: the first he calls proximal, that is something we are attending from; the second he calls distal, which is something we are attending to (p. 11):

"... we are aware of the proximal term of an act of tacit knowing in the appearance of its distal term; we are aware of that from which we are attending to another thing, in the appearance of that thing."

It is probably easier to understand these terms through an example: when one is exploring a cavern using a probe, we are concentrating on the end of the probe which is in our hand, and to what we feel in our hand. So we focus on the near (proximal) part of the probe. But we are not really interested in the vibrations in our hand caused by the probe but in what is on the other end of the probe (far-end, distal part), the cavern. This way we soon forget that we have a probe in our hand and start to picture the cavern. This is meant by attending *from* the proximal *to* the distal. Another example can be how we recognize a face attending from its features to the person.

In particular-entity relation the proximal term indicates the particulars, which we integrate to a coherent entity that we are attending to. Examining the particulars, the understanding of the complex entity may be destroyed (like a pianist concentrating on his fingers). However, the meticulous analysis may deepen the understanding of the entity, if followed by tacit integration/reintegration. This can be the reason e.g. that Ferrari's Formula 1 team claims Michael Schumacher to be a better driver due to his detailed technical knowledge as motor mechanic. There are many cases where the knowledge about particulars is superfluous (e.g. knowledge of the car is not going to improve a driving skill unless you are a Formula 1 pilot or the physiologist knowledge of the body does not invoke a manual skill) and Polányi asserts that it may do irremediable damage on subjects like history, literature and philosophy. The most important message is that the explicit knowledge of the particulars cannot in any case replace the tacit knowledge of them also tacitly integrated into the entity as a whole.

The conception of the tacit knowledge is also at the core of some modern literature of knowledge management, indeed the most influential pieces of these. Nonaka (1991) and Nonaka and Takeuchi (1995) and Takeuchi (1998) claim that recognizing the importance of tacit knowledge was one of the most important factors in the success of Japanese companies (Nonaka-Takeuchi, ibid, p. 8):

"Japanese companies, however, have a very different understanding of knowledge. They recognize that the knowledge expressed in words and numbers represents only the tip of the iceberg. They view knowledge as being primarily «tacit» - something not easily visible and expressible."

Davenport and Prusak (2000, p. 81) suggest that in attempt to capture knowledge within the organization we should focus on tacit knowledge:

"As difficult as it is to codify tacit knowledge, its substantial value makes it worth the effort."

Sveiby (1997, p. 29) warns managers that the knowledge they have to deal with is mostly tacit:

"The question of certainty is of little importance to managers, who have to oper-ate in the real world where one can never be absolutely certain of anything. In con-trast, practical knowledge is important to managers, but it is very difficult to express in words. How do you explain in words how to skate or serve a tennis ball? Practical knowledge is – to a very large extent – tacit."

Minsky (1982 and 1988), starting from the AI perspective, tries to find answer why it is easier to create an expert system than to make a program which could play children's games or bring in the newspaper. In doing so, he came up with a model distinguishing between the special knowledge and the common sense (Minsky, 1988, p. 22):

"Common sense is not a simple thing. Instead, it is an immense society of hard-earned practical ideas – of multitudes of life-learned rules and exceptions, disposi-tions and tendencies, balances and checks. If common sense is so diverse and intri-cate, what makes it seem so obvious and natural? This illusion of simplicity comes from losing touch with what happened during infancy… when we try to speak of them in later life, we find ourselves with little more to say than «I don't know.»"

In other words, the common sense is highly complex and mostly tacit.

The trouble with tacit knowledge is that it is difficult to create models about it. If we build knowledge bases and transfer some of the tacit knowledge into the explicit domain, it is not tacit anymore, so it is not model of tacit knowledge. Polányi created his model and there was really nothing added to it since. This also can serve as a warning for general models of knowledge (meaning here that it is about both tacit and explicit knowledge) to be careful with validation for the tacit domain. That is why for this dissertation only validity for the explicit domain is claimed. It is true that we have no reason to assume that the presented models would work differently in the tacit domain but we also have no reason to assume that they would be the same.

4.1.5. Aspect 4: Intuition, Skills, and Facts

When describing the act of knowing Polányi (1962a, p. 55-65) realized that e.g. when hammering a nail we are differently aware of the hammer and of the nail. What is in the focus of our act, he called *"focal awareness"*; in this case we have focal awareness of driving in the nail; of everything else, in this case of the feeling in our palm, of the hammer, etc., we have *"subsidiary awareness"*. While reading, the meaning of the text is in the focus and there is a subsidiary awareness of the letters, grammatical rules, etc. This conception comes very near to front-of-mind and back-of-mind attention. (cf. Section 3.5) Translating this idea into term of knowledge instead of awareness in the act of knowing we can speak of ***focal*** and ***subsidiary knowledge***.

Baracskai (1997, pp. 107-110) has adopted this last interpretation of Polányi's model and has added a further dimension: the sorts of knowledge; the model was later refined by Baracskai and Velencei (2004a, pp. 43-55). The sorts of knowledge added are the ***facts***, the ***skills***, and the ***intuition***. (See Figure 17)
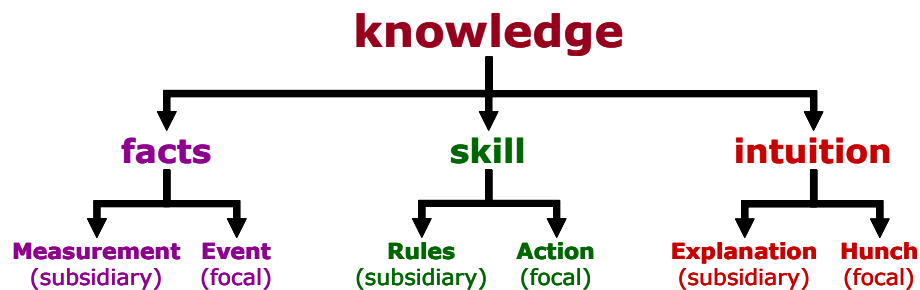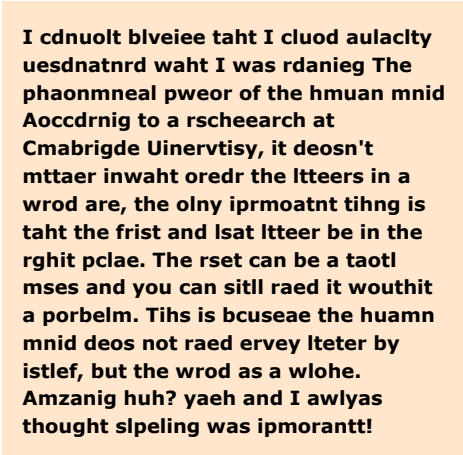
Source: Based on Baracskai (1997, p. 108) including the further developments from Baracskai-Velencei (2004a, pp. 43-55)

Figure 17: The sorts of knowledge.

The essence of the facts is not the correspondence to the reality but the controllability; e.g. we can check in lexicons that Lee Harvey Oswald killed Kennedy, so it is a factual knowledge even if we cannot be sure if it is true. The subsidiary knowledge of the fact is the measurement (i.e. the rules of measuring) and the focal part is the event. The height of the jump of a pole-vaulter is a fact. Its subsidiary part is the knowledge about the measuring standard and how to use it. The focal part is that the bar did not fall down (at a particular distance between the bar and the ground). There

are two types of skills: the crafts (e.g. driving a bicycle) and the social skills (e.g. communication). The subsidiary part is the set of craft (social) rules and the focal is the act. The subsidiary rules are e.g. how to keep the balance and the act is movement with the bicycle. The subsidiary part of the intuition is the set of logical rules, the explanation – always posterior. The focal intuition is the hunch itself, when one senses the solution. The boy senses that the girl is hurt by something he said. This is the focal part of intuition. A follow-up explanation can be given, that he noticed that she has knitted her brows or that her eyes have lost their shine. It might be true but it would be really hard to prove. The essence of the subsidiary intuition is to give a logical explanation of something that happened but it is not known how. The explanation has to follow the rules of the formal logic strictly, either it was how the hunch happened or not. Extending the reading example to two dimensions, the knowledge of letters, while reading, belongs to subsidiary skills. The perception of words is a very complex process; it is waggling between the focal skill and the focal intuition, i.e. recognizing the word is a focal skill and understanding the meaning of the word is a focal intuition. That is the reason why it is often not noticed if a word was mistyped. (See Figure 18)

> I cdnuolt blveiee taht I cluod aulaclty uesdnatnrd waht I was rdanieg The phaonmneal pweor of the hmuan mnid Aoccdrnig to a rscheearch at Cmabrigde Uinervtisy, it deosn't mttaer inwaht oredr the ltteers in a wrod are, the olny iprmoatnt tihng is taht the frist and lsat ltteer be in the rghit pclae. The rset can be a taotl mses and you can sitll raed it wouthit a porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe. Amzanig huh? yaeh and I awlyas thought slpeling was ipmorantt!

Figure 18: Is spelling important?

Dividing knowledge into focal and subsidiary draws far-reaching consequences. Namely the focal knowledge requires front-of-attention and we can pay that kind of attention only to one thing at the same time. (cf. 3.5) It also means that the rest of the 7 ± 2 schemata residing in the STM can only belong to the subsidiary knowledge.

Now we can return to the examination of the difference between knowledge and knowing. Here is a personal story illustrating the way of thinking to help the understanding:

> *During the first years of my apprenticeship with Prof. Baracskai I have heard and learned a lot about the distinction of tacit and explicit knowledge, and also about the distinction of focal and subsidiary knowledge. When my master was explaining to students on his MBA classes the difference between the two, he often used reading as an example; he said that the meaning is in the focus and that the knowledge of letters and grammar are subsidiary. The knowledge of letters and of rules of grammar can be put into words, that is why it can be thought; but we cannot teach in similar way how to write a good poem. This sounded simple and logical. Later I have read translations of Polányi's writings. Polányi said that if a bicyclist bypasses a puddle, she/he will not be able to explain how she/he was keeping the balance during the process but will know that she/he was bypassing a puddle. Thus the focal awareness is explicit and the subsidiary awareness is tacit. Logical again but it is in clear contradiction with the previous. I was curious, although I could accept the contradiction.*
>
> *It is interesting in itself how is it possible that the single most cited piece of literature in knowledge management, Polányi's "The Tacit Dimension" has not been reprinted since 1983 and that I have bought it in "unread" condition for £2.68 – this is the same situation as with Maslow – nobody reads the original work. (cf. Section 3.6) Anyway, finally I read the original in English. It must be noted at this point that in Hungarian language 'knowledge' and 'knowing' are formally the same. At once I have understood the difference…*

It was said in the previous Section that knowledge is a state of mind and knowing is an act. Now, on the basis of the story above, it is possible to get a deeper understanding of this difference. The subsidiary knowledge corresponds to the particulars of the entity and it can be expressed in words. This is how we can learn grammar or

anatomy. The entity cannot be verbalized, it is impossible to explain how to write a good poem or how to kiss. However, when the knowledge is applied in an act of knowing, the subsidiary knowledge is pushed into back-of-mind attention and becomes tacit, while we are able to say what we are focusing on, viz. what is in our front-of-mind attention. It is important to note that in the first case we deal with tacit-explicit *nature of the content* of knowledge, while, in the second case we are tacitly-explicitly *pointing to this content*. (Figure 19)
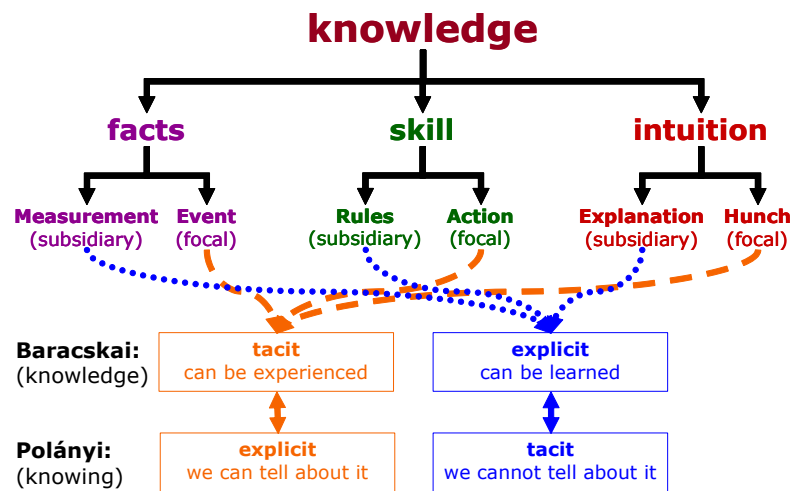
Figure 19: Knowledge and knowing – very different.

It may well be that this shift in interpretation partly accounts for the difficulties of defining knowledge. Now that the difference is clear, we know when we can use knowledge and knowing as synonyms and when not. As this dissertation engages with knowledge increase, the content is important, thus Baracskai's terminology is adopted – the subsidiary knowledge is considered to be explicit and the focal knowledge tacit.

4.1.6.   Aspect 5: Knowledge of "That", "How", "What", "Why"

Another typology of knowledge is based on Ryle's (1949) work, who asserted that not all knowledge can be described as a set of facts and propositions, but that there are also other types. Actually he comes up with one additional type, namely with the knowledge of how we do things, which we cannot necessarily formulate as a list of propositions. There are two other types found during this research, one can also be found in the literature the other one is one of the small results of the present inquiry.

Ryle ([ibid](#), p. 26 ff) started from the assertion that knowledge is usually equalled with the knowledge of true proposition or facts and the relations between them; he calls this approach the *"intellectualist legend"*. However, as Ryle observes, when we attribute an epithet of intelligence[1] such as *"shrewd"* or *"prudent"* or *"silly"* to a person, we are much more concerned with her/his competences than with her/his cognitive repositories, with operations than with truths. Ryle acknowledges that the knowledge of true propositions is *valid knowledge* but he claims that it is not *the only valid knowledge*, i.e. the intelligent act is also to be considered. He calls the former ***"knowing that"*** and the latter ***"knowing how"***.

According to the "intellectualist legend" an action can only be considered intelligent if and only if the person is thinking what she/he is doing while doing it; so the intelligent performance involves observation of rules or application of criteria. It follows that the person first must acknowledge the rules or criteria, and then devise a plan about what is to be done. Borrowing Ryle's ([ibid](#), p. 30) example:

"The chef must recite his recipes to himself before he can cook according to them."

This would mean that "knowing how" can always be traced back to "knowing that". If this is accepted to be true for a working hypothesis, its implications lead to a contradiction[2]; i.e. the assumption that we have to think in advance what to do before doing it, would presuppose that before that we have to devise a plan how to think what we will do, and so on, ad infinitum. There is another detail which is not explained by the "intellectualist legend": what makes us consider the maxims and propositions which are appropriate rather than other thousands which are not appropriate? Finally the "intellectualist legend" also contradicts the observation that the person performing an operation well is often unable to tell the rules she/he followed to perform that operation; e.g. a wit might be able to make good jokes but she/he would not be able to tell us or her-/himself the recipes for them. Thus Ryle showed

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[1] *Here "intelligence" means to involve knowledge.*

[2] *Reductio ad absurdum.*

that "knowing that" and "knowing how" are both valid types of knowledge. Polányi (1962a, p. 31) came to the same conclusion:

"Maxims are rules, the correct application of which is part of the art which they govern. The true maxims of golfing or of poetry increase our insight into golfing or poetry and may even give valuable guidance to golfers and poets; but these maxims would instantly condemn themselves to absurdity if they tried to replace the golfer's skill or the poet's art."

Anderson (1983) arrived at the same categories of knowledge but coined different names for them; he calls the "knowing that" ***declarative or descriptive knowledge***, to emphasize that we store this kind of knowledge in form that can be verbalized; and the "knowing how" he named ***procedural knowledge*** to call attention that this kind of knowledge manifest itself in procedures we perform.

To perform certain operation correctly or efficiently or successfully is not enough to gain the attribute of knowledge. It is not enough if the action is well-regulated, the person has to be able to regulate her/his own action, to detect and correct lapses, to repeat and improve upon success, to learn from others' examples, and so forth. This distinguishes the act of a knower from a well-regulated clock or from a parrot accidentally saying one of its sentences when they sound wise or from sheer habits. Thus the listed attributes of the knower performing an act are all part of "knowing how".

If we dig deeper, we can find a further two categories that are still not covered. For one, if we do know how to perform a certain operation and detect and correct the mistakes and also to improve the process, it is not necessary that we would have also been capable of creating this "how" knowledge. So there seems to be a deeper understanding, which is necessary to create a novum, although, we can polish an existing process without it. To adopt a similar term to "knowing that" and "knowing how" this missing knowledge category could be named *"**knowing why**"*; this is the knowledge of the problem solver, or, in this dissertation, the knowledge of the scientist. Gurteen (1998, p. 5) also uses a cook as an example: if there is an ingredient missing from your cake, knowing why that ingredient was part of the recipe might help you finding a substitution:

"In fact, know-why is often more important than know-how as it allows you to be creative – to fall back on principles – to re-invent your know-how and to invent new know-how."

To find a shortcut to the second missing knowledge category consider once again the cook from the previous examples: he can make a haggis and a strawberry truffle (amongst others) without reciting the recipes to himself, as he "knows how". But, which one to make *tonight* for *her*? This is different from knowing *how* to make them or *why* to make them. This is about what to do – this new knowledge category we can call *"**knowing what**"*. This is the kind of knowledge the leader needs.

The latter two knowledge categories can be considered to be parts of "knowing how", and they probably were by Ryle. However, there are additional advantages resulting from creating new categories for them (e.g. to distinguish the dominant knowledge of the leader and the scientist from other), which is enough to justify the refinement of the original model.

Investigating "knowing what" Minsky (1994) concludes that besides what she/he has to do the expert of the domain will also know what she/he must not do. So, the positive knowledge (knowing what to do) differs from negative knowledge (knowing what not to do). Both are essential. E.g. on a website we have to use strong signs to attract the attention of the surfer to keep them there for a while but we have to avoid the negative strong signs at all costs as they would scare the surfer away. Or the cook from the previous example also knows what would be the certain failure for her tonight. The conception can also be generalized to "knowing that" (e.g. 'I do not know who it was but I am certain that it was not him.'); to "knowing how" (e.g. a mechanic is often not certain, at a moment, how to repair the car but there are things he would certainly not do in the present situation); and to "knowing why" (e.g. the novice problem solver is likely to start her/his research in many directions and one of the important roles of the master is to cut most of these directions, leaving a few that are promising).

4.1.7.　Aspect 6: Representations of Knowledge

Knowledge representations are about how knowledge is stored in our LTM. This topic has strong connections to the knowledge typologies discussed previously, as it is usually assumed that different types of knowledge are also stored differently – thus the different representations. There are two large overlapping fields of inquiry about knowledge representation, the investigations of the human and of the artificial representations. Here they are not distinguished as the results relevant for this dissertation are in the overlapped part. Researches of knowledge types and knowledge representations mutually influence each other.

Representations are kinds of models of the thing they represent; the representing world and the represented world should be distinguished and it can be examined how they correspond to each other. What we want is to draw conclusions about the represented world by examining only the representing world. Thinking in knowledge representations also makes it easier to understand and keep in mind the idea of constructivism – i.e. that our representation of reality evolves as result of interaction of that reality and our knowledge. (cf. Section 3.4)

Rumelhart and Norman (1988) speak about four categories of representation, more precisely four foci of research of knowledge representations. They emphasize that our actual representational systems are hybrids falling into more than one of these categories. The term "representational systems" indicates that they include, beside knowledge representations, also the processes that operate upon these representations.

The ***propositional representational systems*** were the first to be investigated. For a long time it was considered to be the only kind of representation in the same way as the declarative knowledge, to which it corresponds, was considered to be the only knowledge type. What all propositional representational systems have in common is that they are collections of symbols and their relations. In the first attempts to model the meaning (Rumelhart-Norman, ibid, pp. 511-514) researchers tried to make use of bivalent logic, more precisely of predicate calculus. In these representational systems knowledge is represented as a system of statements. This is the actual reason that

these simplest propositional representational systems are the most useful when we want to represent knowledge that can be expressed in form of simple statements, they do not actually capture the meaning. The inadequacy is the most striking if we try to account for similarity and metaphors.

Based on Chomsky's (2002)[1] prior work on syntactic and semantic structures Quillian (1967) has developed the conception of semantic networks, trying to represent the knowledge in LTM by a kind of directed graph, where the nodes are concepts and the relations are associations. The idea was to capture the meaning of a concept in a node from the pattern of its relationships. These versions of propositional representational systems give much better account for similarities, but they still fall on metaphors. This is probably the reason that Rumelhart and Norman (ibid) argue for multiple representations. There are two important side-effects of this conception: (1) It provides a direct account for the hierarchical structure of schemata, which, in turn, explains the need for feature inheritance of concepts in the semantic network. (2) Measuring the 'distances' between concepts was based on this idea; the survey lead to unexpected findings that our hierarchies of concepts are tangled. (Mérő, 1990, pp. 63-67)

The conception of ***analogical representational systems*** is developed to account for the handling of images. There are certainly some parts of our knowledge that are not like symbols (concepts) and their relations but rather something like images. These representational systems should not only account for standalone images but rather objects going through various transformations. We do not only remember transformations that we have previously seen but we can create other transformations by only imagining them. These mental transformations seem to have something important in common with real transformation, more precisely with how we would perceive the real transformations, e.g. there is a limited spatial extent. The analogical representational systems are usually explained and examined using real images or 3D spatial models, but we can easily imagine that we do something similar in case of abstract mental models, what is probably the reason that Rumelhart and Norman (ibid)

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[1] *The first edition was published in 1957.*

insist on term *"mental model"* to avoid the unnecessary limitation. As we are able to generate a series of mental transformation we can say that we are capable of mental simulations; e.g. thus we can determine functional properties of an object but this is also how we can perform complex thought experiments. (cf. Section 2.3) This would also mean that we can make endless lists of statements about a mental model, which is one of the ways to make a part of tacit knowledge explicit. Actually this is what the knowledge engineer often uses to elicit the knowledge of an expert. A trivial example would be if we ask one how many windows there are on a building one knows – one usually recalls the image of the building from LTM to STM and then counts the windows.

The ***procedural representational systems***, as the term suggests, correspond to procedural knowledge, to knowing how. Some researchers were/are suggesting that behind the procedural representation there is a propositional one, in the same way as computer programs and the data they work with are stored in a same form according to Neumann's principle. After all, they can argue, the processes can be expressed in form of «if… then» rules. However, it seems that we have knowledge of processes different than that of propositions, at least some processes – this is what Rumelhart and Norman ([ibid](), pp. 562-566) are suggesting. Nevertheless, the program-analogy is adequate for thinking about processes stored in our knowledge. The processes stored in the real sense of procedural representations are not available for inspection, they operate more efficiently and there are heuristics encoded in them; they allow us to tailor how the knowledge is represented to best fit the particular activity. It is an interesting question what triggers a process? There are two possibilities: either they are invoked directly by another procedure or an interpreter or they are monitoring what is going on and when the initial conditions are appropriate they get into action. Both ideas also served as basis to build computer programs.

The ***distributed representational systems*** are not really a different kind of representation; rather it is a conception underlying any or all of the previous three. The conception of distributed representation means that the different pieces of knowledge are not stored locally but somehow everything is stored everywhere; much the way as internet works. Although this conception has significant importance for software

design and especially AI it did not result in major advance in understanding human knowledge. This is probably the reason that MacEachren (1995, pp. 170-209) kept only the first three of the previous representation, providing additional evidence on them from cartography. He also describes different types of cognitive schemata for different representational systems; he develops a concept of map-schemata, which suggests that there could be a variety of schemata-types.

4.1.8.   Aspect 7: Levels of Knowledge

The levels of knowledge are about knowing more or knowing better – although we shall see that it is not purely about some quantity. The knowledge levels were defined by Dreyfus and Dreyfus (1986, pp. 19-36), who distinguished five qualitatively different levels: the novice, the advanced beginner, the competence, the proficiency, and the expertise. The difference between the levels is not totally clear in this model, Mérő (1990, pp. 119-121) and Baracskai (1999, pp. 98-101) defined clearer categories. These categories are essentially the same as the latter four of Dreyfus and Dreyfus, as Mérő and Baracskai do not consider the absolute beginner with no knowledge of the domain at all. This is reasonable as usually once we officially begin to engage into a discipline we already have some knowledge of it. Mérő and Baracskai came to the same categories using the number of cognitive schemata. For the first two levels both Mérő and Baracskai use the same name, the first is called 'beginner' and the second 'advanced'; the third Mérő calls 'candidate master' and Baracskai calls 'expert'; the fourth both of them call 'master' or 'grandmaster'. The names of the last level are borrowed from chess, as most of what we know about the knowledge levels is coming from the experiments with chess players. In this dissertation Baracskai's terminology is adopted as I am more familiar with this one.

If we imagine knowledge as an image created about the reality, what and how much one sees of the reality by a discipline depends much on the number of her/his cognitive schemata in the discipline. A person with no schemata in the discipline at all will see nothing. She/he is an amateur in that particular discipline. The beginner level is a few ten schemata, the beginner will see only few elements, and she/he will see them indistinctly. She/he would not know which element to connect to which one

or how to do it. As she/he knows so little about the discipline, she/he will try to apply her/his everyday schemata. The advanced, with several hundred schemata of the discipline, will see quite a lot of elements, though most of them indistinctly. She/he will manage to connect some of them assembling smaller-bigger component images, though she/he will fail to join up the component images. The expert possesses several thousands of schemata of the discipline; she/he will see all the elements and every connection between the elements (or the component images). She/he will see every detail that is possible to see but the image. The (grand)master of the discipline has several tens of thousands of professional schemata; she/he will not see that there are elements at all; she/he will see the image itself, losing the details.

All the researchers from the field emphasize that on the levels below the master's we are able to put into words what we see. The beginner will usually talk about it mistakenly, since she/he can see no relations and the elements themselves are also indistinct. The advanced will count and measure everything, the expert will describe everything accurately measuring what is measurable, and not measuring what is immeasurable. (Velencei, 1998) To think about the elements, details of the image we need concepts (words). At master level this role of the concepts vanishes; the master senses the image directly, she/he steps into it. As a consequence the cognition of the master is intuitive, it cannot be otherwise. She/he will say how things are, what is to be done, and she/he will not be able to tell us about the reason for it, or how she/he would come to that. Just like that. Because it cannot be otherwise.

The qualitative difference between the knowledge of the master and the others is usually explained by the high proportion of meta-schemata in master's knowledge. However, the meta-schemata already appear on advanced-level and there are lots of them on expert-level. The extremely high complexity of the master's meta-schemata is a better explanation but not necessarily satisfactory. During the present investigation the niche-induction was applied specifically to study the differences of the knowledge and the knowledge increase of the master and the others; and it was observed that there is also something else. As Baracskai has put it "the master sees the world through her/his discipline". It can be said that at master-level a supra-schema evolves, which frames up all the meta-schemata of the discipline. Unfortunately, this

was already recognized by Mérő ([ibid](), p. 193) – so it cannot be one of the sideway results of the present research:

> *"Perhaps the feeling of enlightenment can also be conceived as the activization of a cognitive schema that is simultaneously the meta-level of all our cognitive schemata, but itself has no meta-level. Unfortunately, I cannot think of any laboratory experiment that could possibly prove even the faintest aspect of such statement."*

The master-level knowledge is a general limit to LTM – no one can have more cognitive schemata than a few tens of thousands[1]. This also determines the possible number of schemata in a discipline. A discipline cannot be 'bigger' than how much can fit into the head of a master. It seems that a paradigm can appear when a discipline reaches the expert-level, and, once it gets over the master-level, the discipline breaks up or a part of it forms a new discipline. This happened first to the philosophy; the scientific disciplines separated from it one by one. It also happened to physics; today there is no physics anymore, there are quantum-physics, astronomy, fluid-mechanics, and so on. This is also the reason that there are no polyhistors anymore; Aristotle was a scientist (mathematician, physicist, biologist, etc.), a philosopher, a physician, military strategist – it was easy to be a polyhistor when all the human knowledge could be stored in the Bibliotheca Alexandrina. These statements form a hypothesis, starting material for future investigations – side-effects of the present inquiry.

The original intention regarding the present investigation was to abandon the examination of the master-level knowledge as there are far too many tacit elements to build a model for them. However, it is immensely interesting to try to understand the knowledge of the master. Thus the master-level knowledge and knowledge increase is often mentioned throughout the dissertation, even though the result is not claimed to be valid for the master. Nevertheless, it is very instructive to observe the differences between the master and the others – it helps understanding the knowledge and the knowledge increase at all levels.

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[1] *Usually estimated between 50,000 and 100,000 ([Mérő, ibid](), p. 125)*

4.1.9. Aspect 8: Value of Knowledge

The previous sections described knowledge from various aspects. These aspects are used in the present dissertation to gain better understanding of knowledge and to find the limitations to the validity of the results. One of the results, the MLW, is concerned with the willingness of the individual to accept a particular new knowledge. This willingness is a value judgment born from the interaction of the personal and the organizational value systems. To prepare the ground for the discussion of this interaction in this section, the personal and organizational value judgments of knowledge are introduced based on Section 3.3.

There are two kinds of value judgments about knowledge in case of both the personal and the organizational value systems; one is the value judgment about the particular knowledge and the other is about the knowledge in general. In the present discussion the first is called the judgment and the second the meta-judgment.

For individuals today, knowledge rarely carries any survival value (most of us is rarely in a situation when knowledge of something would save our lives), it usually has some adaptive and utilitarian value (better work performance and/or career progress), but mostly it belongs to our symbolic value-universes (we may believe that we are worth more if know more or that knowledge is power, we may desire understanding the world – this value is the premise of any scientific work). On the contrary, to organizations today, knowledge literally has survival value.

There is a problem about determining the value of a particular knowledge, apart from those already described in Section 3.3 (i.e. that our values are unquantifiable, that they cannot be aggregated, that we do have all the information about, and so on). To determine the value of knowledge we would need to know everything about its future usefulness (i.e. what the particular knowledge will be good for in the future), the usefulness of all knowledge acquired with this knowledge as basis, and so forth ad infinitum. Popper (cited in Popper, 1961, pp. xii-xiii) has shown that it is impossible to have this kind of evaluation. The argument itself is rather complicated but a sound reasoning can be given for illustration (ibid, p. xii):

"... if there is such a thing as growing human knowledge, then we cannot antici-pate today what we shall know only tomorrow."

This means that we have some other way to make value judgment about the knowledge, i.e. do we like it, is it interesting, and so on. The situation will be further complicated in Section 4.2.9 by acknowledging that we have to judge a knowledge which we do not yet possess – for now we shall lay aside this discussion and focus on meta-judgments.

As our individual meta-judgments of knowledge mostly belong to the domain of symbolic value-universes, they demonstrate great diversity. It is easy enough to un-derstand our own relationship to knowledge, i.e. to understand our meta-judgments; although this does not mean understanding why we like a particular piece of knowl-edge but we usually know whether we like it or not. Everything that was said about the personal value systems in Section 3.3 applies here.

Understanding organizational meta-judgments is more difficult. We shall assume that the organizational value system is already formed and it has its own 'life'. (cf. Section 3.3) This means that, similar to the personal value systems, everything that was said in Section 3.3 applies to organizational value system as well. But the meta-judgments at work mean taking into consideration the consequences of how the value system is presented to the members of the organization. This is described, in this dis-sertation, in terms of 'knowledge orientation' of the organization.

It is emphasized by many authors, e.g. Drucker (2002), Nonaka and Takeuchi (1995), Davenport and Prusak (2000), Sveiby (1997), and Nordström and Ridder-stråle (2002), that knowledge is an essential asset of organizations today and it was already discussed throughout the present chapter. This is meant by the expression that knowledge has a survival value for organizations. There are, however, pitfalls that should be observed.

The non-knowledge oriented organization would be one that does not value knowledge; there are very few areas today where such organizations can survive; thus these are not considered here. We can assign different grades to the knowledge

orientation of the organization. (Figure 20) The lowest grade of knowledge orienta-
tion is if the *knowledge* is the high value. Davenport and Prusak ([2000](#)) list numerous
examples showing how this approach can lead to undesired consequences; i.e. if in
an organization knowledge is assigned a high value, it can easily be interpreted that
the exclusive ownership of knowledge is rewarded. Thus this approach may prevent
knowledge sharing, even though the knowledge is considered valuable.

The next grade of knowledge orientation is when the *knowledge sharing* receives
high value. This means encouraging people to share their knowledge instead of keep-
ing it for themselves. However, there is still a danger in this approach: if only those
having knowledge and sharing it are rewarded, often it is supposed that the one who
wants to learn is stupid – she/he does not have the knowledge.
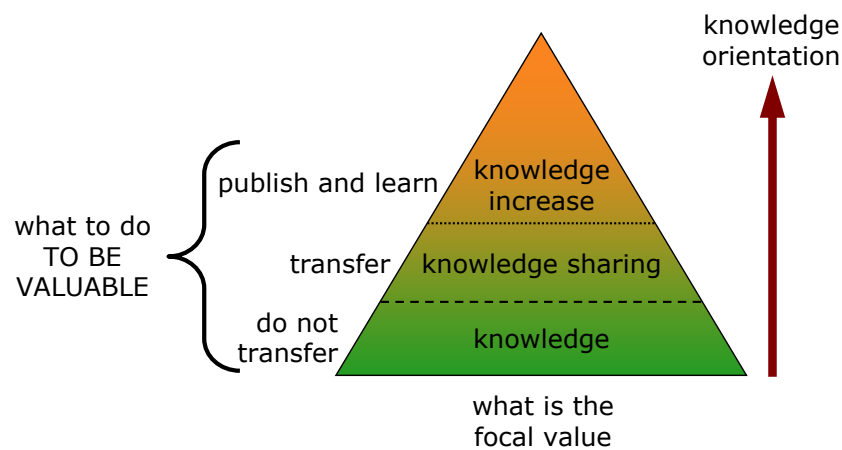
Figure 20: Knowledge orientation of organizations.

Therefore, the highest grade of knowledge orientation is if the knowledge increase
is assigned high value: share your knowledge, disperse it and learn new things all the
time. The one who learns is also rewarded. This is coherent with Senge's ([1990](#))
conception and with the approach of Lehaney, Clarke, Coakes and Jack ([2003](#)) that
the real competitive advantage is if the people at all levels in the organization learn
and they learn faster than the competitor.

The knowledge orientation of the organization tells us about the organizational
meta-judgment of knowledge and we have seen that the highest level of this is if the
knowledge increase is valued. This section focused on the value of knowledge for
organizations and, after the knowledge increase is described in the next subchapter

along the same aspects as the knowledge was in the present subchapter, we shall return to examination of the value of knowledge increase in section 4.2.9. This individual and organizational valuation of knowledge increase will be used to create the Model of Learning Willingness.

4.2. Knowledge Increase

> *"Asking good questions is half of learning."*
>
> *Sufism[1]*

The term knowledge increase refers to the increase of personal knowledge and it should be distinguished from the growth of knowledge which is used (as e.g. by Popper, 1992 and Munz, 1985) in relation with the altogether knowledge available in mankind. The term of learning is sometimes used in the same sense in the literature (e.g. by Bower-Hilgard, 1985) but different authors use it differently. In this thesis learning is used for a certain type of knowledge increase and will be more precisely explained; for now, just to give a metaphor, it is the 'classroom-type' knowledge increase.

The purpose of this subchapter is to introduce the second part of the preliminary model, i.e. the knowledge increase as a process occurring in the system of knowledge, and to examine this process along the same aspects that were used for the examination of the knowledge in the previous subchapter.

Similar to the previous subchapter, this one is also divided into nine sections; the first gives an overview of the definitions of knowledge increase from literature, and the other eight discuss the aspects of the investigation. The first one explains the process of knowledge increase as interaction of cognitive schemata, the second describes the personal nature of knowledge increase, the following five examines knowledge increase along the typologies introduced in the previous subchapter, and one section discusses the value of knowledge increase from the viewpoint of both the individual and the organization.

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[1] *Essential Sufism (http://www.katinkahesselink.net/sufi/quotes.html).*

As some of the properties of knowledge presented in the previous subchapter are in literature examined only from the viewpoint of knowledge and not from the viewpoint of knowledge increase, this subchapter contains a lot of added value in the form of developing further the previously introduced conceptions and examining the consequences. Similar to the previous subchapter, some of the descriptions are based on observations made during the present research.

4.2.1.   Definitions of Knowledge Increase

Knowledge increase can be described as acquisition of new knowledge (Bower-Hilgard, 1985, p. 8), i.e. at one time a person does not possess some knowledge and at a later time she/he does. The knowledge increase is the process of transition from the first state to the second.

The predecessors of the conception of knowledge increase came from behaviourists and they regarded learning as change in behaviour which cannot be explained otherwise (Bower-Hilgard, 1985, p. 11):

"Learning refers to the change in a subject's behavior or behavior potential to a given situation brought about by the subject's repeated experiences in that situation, provided that the behavior change cannot be explained on the basis of the subject's native response tendencies, maturation, or temporary states (such as fatigue, drunkenness, drives, and so on)."

Many objections are possible to this definition; the difference in knowledge may or may not manifest itself in change of behaviour, as humans are capable of abstraction it may manifest itself in a completely different situation, knowledge cannot be totally separated from the temporary (or permanent) states[1]; and, finally, the source of new knowledge may be other than a repeated experience. However, it is understandable that those denying the mere existence of consciousness (i.e. the hard-line behaviourists) came to such a definition. Some of the objections are overcome by the ideas of Gestalt and cognitive psychology.

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[1] *For an arachnophobic it makes no difference if she/he had learned that the spider on her/his hand is not dangerous – she/he will still panic.*

The first conception on learning[1] was developed by Thorndike ([1911](#)), who started from empirist roots of behaviourists – even though much of his work was done before the appearance of behaviourism – supposing that we can only talk about learning in terms of inference from changes in performance. He assumed that there is an association or connection between the sensory impressions stimuli and the response, thus this school is often referred to as *associanism*, *connectionism*, and, most of all, *stimulus-response (S-R) model*. He built up his conception of learning from trial-and-error by means of mechanistic rewards-nonrewards (success and failure), in his later work assigning much more significance to reward than to punishment. The response to new situation should be based on similarity to a previously-learned situation. Paraphrasing Alfred North Whitehead[2], we could say that in the first half (or more) of the previous century conceptions about knowledge increase were no more than a series of footnotes to Thorndike.

There were two significant conceptions in behaviourist school growing out from Thorndike's work; one was Pavlov's ([1927](#)) conception of *conditioned reflexes* also called *classical conditioning* and the other Skinner's ([1950](#)) conception of *operant conditioning*. The difference between the two is that in Pavlov's model, the reinforcement is connected to the stimulus while in Skinner's model it is correlated with the response. There are two kinds of reinforcements, the positive is a reward and the negative is a removal of an unpleasant stimulus; the two kinds of punishment can be similarly constructed. Skinner carried out his experiments with rats in the Skinner box but had grandiose plans to apply his ideas in an engineering society. Boulding ([1985](#), p. 163) commented on this idea:

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[1] *They use the term "learning" so it is used here as well, although it means something different for them than as it will be used later on in this dissertation. Before it is used with this different meaning, the concept of learning is going to be re-defined (or, more precisely re-described). The term "knowledge increase" cannot be applied here as there supposed to be no knowledge as it is understood in this dissertation.*

[2] *He said once that "The safest general characterization of the European philosophical tradition is that it consists of a series of footnotes to Plato."*

"Psychologists assume rather easily that they know what constitutes positive and negative reinforcements, and perhaps in rats they do, although I am not even sure of that."

Most of the work done in the behaviourist school since was the application of advanced mathematics and technology; the first was used to make more complex models of the same sort applying probability theory, and the second made possible more diverse measurements with increased precision. The only exception is Tolman ([1922](#) and [1948](#)) and his followers, who seem to have adopted a number of ideas from Gestalt and cognitive psychology while remaining in behaviourist school – actually aiming to modify the behaviourist mainstream. They acknowledge purposiveness in behaviour and the role of knowledge, intention, thinking, planning, and reasoning. This resulted in S-R model becoming an *expectancy model*, meaning that one gives a particular response to a stimulus because one is expecting another stimulus after the response; Tolman's model is also referred to as *purposive behaviourism* or *S-R-S model*. The importance of this direction of development is that humans are not anymore considered being black boxes without consciousness.

The human knowledge increase was first studied by Ebbinghaus ([1913](#)), as it was already mentioned in Section 3.4, but his work can still be considered as a member of the association family.

The Gestalt psychologists adopted a different starting point; instead of the empirist tradition used by Thorndike and his followers, the Gestalt school of learning starts from rationalism. First they developed conceptions and then tried to interpret familiar observations using these conceptions. The same approach was used in the thought experiments during the preset research. Köhler ([1959](#)) was the first to talk about insightful learning, i.e. the "Eureka!" experiences in apes when realizing instrumental value of tools. This was contrasted to Thorndike's trial-and-error. The Gestalt psychologists were more interested in perception than in knowledge increase but their results influenced the field significantly. The wholist conception of perception, i.e. that the whole emerges from particular arrangements of elements, is widely accepted today ([Bower-Hilgard, 1985](#), p. 310), not only for perception, but also in systems approach (cf. 3.2), and in this dissertation it is also how the nature of cogni-

tive schemata is described. The Gestalt approach is sometimes considered to be part of cognitive approach and other times it is said to be adopted by the cognitive psychologists.

Cognitive psychology uses the model of information processing (Bower-Hilgard, 1985, p. 355) as starting point to describe knowledge increase. An explanation of this conception was outlined in Section 3.4 and further details in terms of knowledge increase will be given in the next section, based on previous discussion of cognitive schemata in Section 4.1.2. The cognitivist conceptions are strongly related to the developments in AI (See Section 3.7), which can be considered as a synthesis-model of cognitive approach as opposed to analytic approach of behaviourists.

The most comprehensive difference between the behaviourist and Gestalt and cognitivist conceptions of learning is what they say is learned: according to behaviourists a habit is acquired; according to Gestalt psychologists and cognitivists, cognitive structures are acquired (although this also applies for Tolman's version of behaviourism). This review of the different approaches to knowledge increase aimed to provide a historical background, in the present dissertation, the Gestalt/cognitivist approach is adopted.

There were different classifications of knowledge in the previous subchapter and the presented conceptions of knowledge increase account for increase of some types. In forthcoming sections the knowledge increase is examined according these typologies. As (Bower-Hilgard, 1985, p. 15) has put it:

"... learning is more like a chapter heading than a technical term in contemporary psychology, and the term continues to serve a useful function in non-technical contexts."

4.2.2.   Aspect 1: Process of Knowledge Increase

The knowledge increase is regarded in this dissertation as a level 4 (i.e. heuristic) process occurring in a system of knowledge which is of level 7 (i.e. human system). (cf. Section 3.2) During the knowledge increase, a new knowledge is received and

incorporated into the existing knowledge, and then the increased knowledge is formed. (Figure 21) The source of new knowledge is called the available knowledge. The available knowledge is considered to be the knowledge filtered by the accepted paradigm. The new knowledge is considered to consist of a single cognitive schema; this makes the modelling easier and actually imposes no restriction for two reasons: First, the new knowledge, if delivered well, can be organized into a single meta-schema. Second, if multiple schemata are received they can be regarded as multiple learning processes.

a)

b)
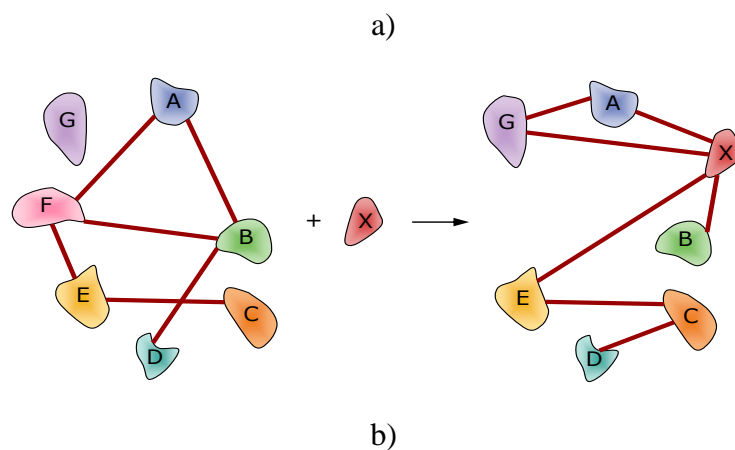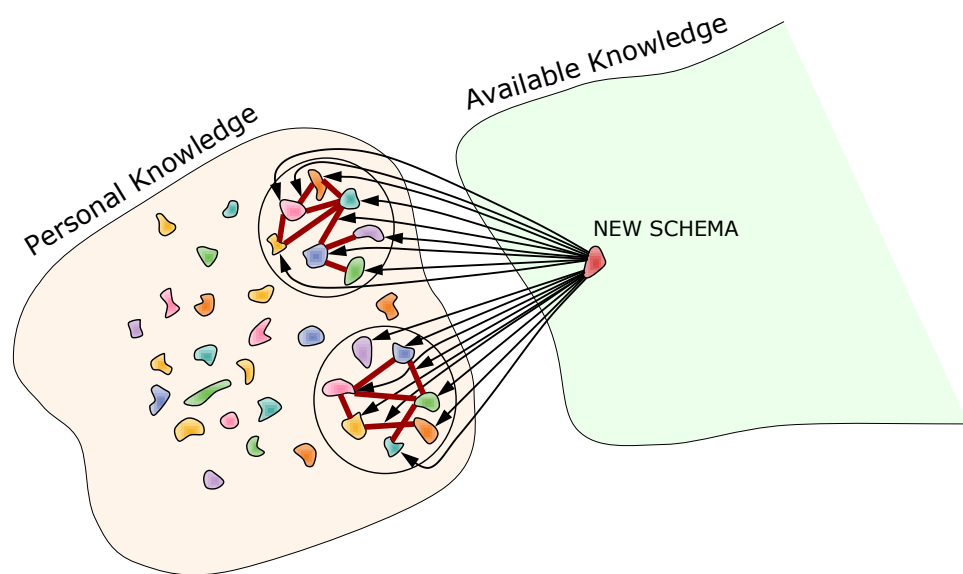
Figure 21: Absorbing a new schema.

It was shown in Section 3.4 that cognitive processes are constructive, and this applies to knowledge increase as well, as it is a cognitive process. This has a significant consequence for the knowledge increase, i.e. we cannot incorporate the new knowl-

edge if we do not have existing knowledge to which we can attach it. In terms of cognitive schemata, it means that we need schemata and/or groups of schemata to which the received schema can be attached. It was also said that a schema can belong to multiple meta-schemata, and this means that it can be attached to different meta-schemata at the same time.

If knowledge was additive, knowledge increase would be a very simple process, namely we should only add new schema to the existing ones. However, this process does not work. When incorporating a new schema, it may transform or replace existing ones, and it may break or modify existing relations between the existing schemata, and therefore it may transform existing structures as well.

Part a) of Figure 21 shows the process of a new schema connecting to two groups of schemata. Part b) zooms the connection of the new schema to the bottom group. New schema *X* connects to the group of schemata **A-B-C-D-E-F-G**. It connects itself to schemata *A*, *B*, *E* and *G*; it displaces *F* dismissing its connections to *A*, *B* and *E* as well; due to its effect *G* establishes connection with *A* and *C* connects to *D*; the connection between *B* and *D* breaks off.

If there were no other ways of knowledge increase, the knowledge of certain individuals would little by little equal the available knowledge (respectively a part of it, which can be described by few ten thousand schemata and which can therefore fit into an individuals LTM). The available knowledge and the total knowledge of all individuals together would have never been increased. The increase of the available knowledge is up to scientists.[1] The essence of the thinking of the scientist is to gain new knowledge by rearranging her/his existing schemata, their relations and structures. It will be shown that the model developed for this dissertation is also appropriate to interpret the knowledge increase of the scientist – although this kind of knowledge increase is not investigated.

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[1] *Here the scientist is a metaphor for the problem-solver – i.e. not only the scientific knowledge can be increased –, understanding problem solving as creation of new knowledge as described at the beginning of Chapter 2.*

Incorporating the new knowledge the personal knowledge becomes more complex. On the basis of Popper's already mentioned conception (cf. Section 4.1.9) Baracskai and Velencei (2004b, pp. 68-69) has developed the principle of doubtful knowledge, according to which the more complex knowledge is more doubtful. So we endeavour making our knowledge more doubtful. This seems to be a paradox only at first glance. If we consider a simple statement *'Tomorrow it is going to rain'* and another *'It is going to rain tomorrow and the day after tomorrow'*, we can see that the second (which is more complex) is more doubtful that the first one. This idea explains e.g. that a scientist must not be dogmatic; she/he must consider his results temporary – as new knowledge resulting from her/his research reveals more complexity, thus shedding more doubt than the previously existing knowledge. Only knowledge consisting of a few very simple elements is not doubtful, such as knowledge of elementary physics and mathematics. If there are plenty of these simple elements they form a complex knowledge which is doubtful, such as modern physics and mathematics. The one owning a watch always knows the right time; the one owning two watches never does.

4.2.3.   Aspect 2: Increase of Personal Knowledge

Similarly to Section 4.1.3 the conception of personal knowledge will be used, only this time it happens regarding the knowledge increase. It was said in the mentioned Section that all knowledge is personal; meaning that all of it is knowledge of an individual and that it is in interaction with the whole personality of the individual. This is also true for the knowledge increase: it is always the knowledge of the individual increased, and the process of knowledge increase is also in constant interaction with the whole personality of the individual. The increase of scientific knowledge is not different (Gleick, 1988, p. 182):

"The scientific world can be surprisingly finite. No committee of scientists pushed history into a new channel – a handful of individuals did it, with individual perceptions and individual goals."

Our knowledge increase begins in highly personal manner, i.e. by imitation. The same happens to novices of science as well (Polányi, 1964, p. 43):

"Speech is learned by intelligent imitation of the adult. Each word must be noted in a number of contexts until its meaning is roughly grasped; it must be read in books and used for some time in speech and writing under guidance of the example of adults in order that its most important shades of meaning are mastered. This training can be supplemented by precept, but imitative practice must always remain its main principle. The same is true of the process by which the elements of the higher arts are assimilated. Painting, music, etc., can be learned only by practice, guided by intelligent imitation. And this applies also to the art of scientific discovery."

This model of knowledge increase is the master-apprentice relationship, which was the dominant form of learning not only in science but in many other fields as well. Today it is somehow out of fashion, which can be detected e.g. in changes of the terms used for doctoral students: first it was a master-apprentice relationship, later a mentor-student relationship, now it is a supervisor-supervisee relationship. (Baracskai-Velencei-Dörfler, 2005) Further discussion of the master apprentice relationship follows in the forthcoming sections in this chapter; aiming to show that it is immensely important.

The increase of personal knowledge takes place in organizational context. This will be taken into account in the present investigation in MLW, however, it is necessary to make two concepts clear: the *'organizational learning'* and the *'learning organization'*, similarly to the concept of organizational knowledge in Section 4.1.3. Both are matters of value systems.

The organizational learning is about the impact of the organization on the personal knowledge increase of the members of the organization (Senge, 1990, p. 3):

"... we can then build «learning organizations», organizations where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together."

The learning organization sometimes refers to organization where the organizational learning happens; at other times it is about the relation of the organization to changes in external environment, as it was describe by Argyris and Schön (1978) in the conception of single-loop vs. double-loop learning.

The increase of personal knowledge of its members is not the only way for the organization to increase its knowledge capital. There are other knowledge assets in the organization besides the personal knowledge of its members. There are knowledge bases which store knowledge acquired from experts in a codified form; knowledge can be embedded into business processes of the organization or into its products and services. These are kinds of *'frozen'* knowledge, meaning that they can make the business processes go on, they can be applied in the form in which they exist but they do not have the *'live'* features of knowledge to increase and to adapt to new circumstances as human knowledge does. To activate these features the knowledge should become personal knowledge of an individual again, and then it can go through knowledge increase; later it can be embedded into a new or updated 'frozen' form.

It was indicated in Section 4.1.3 that an important role of managers is to preserve organizational knowledge assets; building knowledge bases is an obvious way to achieve this. It is, of course, impossible to codify all the knowledge available within the organization (Davenport-Prusak, 2000, p. 69):

"Codifying all corporate knowledge would be an immense and futile undertaking, similar to and even more difficult than the mostly futile efforts undertaken to deploy enterprise-wide data modelling. As Patricia Seemann, a consultant and former managing director of the Right First Time knowledge project at Hoffmann-LaRoche, says, «Relevance is far more important than completeness.»"

The other way for organizations is to encourage knowledge sharing (Davenport-Prusak, 2000, p. 71):

"... the codification process for the richest tacit knowledge in organizations is generally limited to locating someone with the knowledge, pointing the seeker to it, and encouraging them to interact."

The combination of these is suggested by Nonaka and Takeuchi ([1995](#)) as the way of focusing the organizational efforts on knowledge; this approach is described by the metaphor of a knowledge spiral as means of organizational knowledge creation.

So the conceptions of organizational learning and of learning organizations are very important, but it is as well important to use them correctly. Further details on the importance of personal knowledge increase for the organizations follow in Section 4.2.9. Like knowledge, knowledge increase is also a highly personal enterprise involving the whole personality of the individual; some of these personal factors are taken into account through the MA.

4.2.4.   Aspect 3: Increase of Tacit and Explicit Knowledge

Polányi ([1966](#), pp. 6-19) originally described the increase of tacit knowing as a tacit process; and the structure of the process of knowledge increase can be described in the same manner as tacit knowing, in terms of proximal and distal parts. For instance in the already mentioned (Section 4.1.4) experiment, the experimental subjects were presented with a large number of senseless syllables and administered an electric shock after certain syllables. The subjects then showed symptoms anticipating the electric shocks after these syllables, without ever becoming aware of it. Or, we learn to recognize different moods on peoples' faces without ever being able to tell what signs we identify on these faces. Sometimes the tacit knowledge is still taught using classroom exercises, or demonstrations by pointing to objects. Polányi ([1966](#), pp. 5-6) explains that this still involves tacitly acquired components:

"But can it not be argued, once more, that the possibility of teaching these appearances by practical exercises proves that we can tell our knowledge of them? The answer is that we can do so only by relying on the pupil's intelligent co-operation for catching the meaning of the demonstration. Indeed, any definition of a word denoting an external thing must ultimately rely on pointing at such thing. This naming-cum-pointing is called «an ostensive definition»; and this philosophic expression conceals a gap to be bridged by an intelligent effort on the part of the person to whom we want to tell what the word means. Our message had left something behind that we

could not tell, and its reception must rely on it that the person addressed will discover that which we have not been able to communicate."

An important form of increase of tacit knowledge is the previously mentioned master-apprentice relationship. The precondition is that the disciple must believe that the master knows (Polányi, 1962b):

"... the methods of scientific inquiry cannot be explicitly formulated and hence can be transmitted only in the same ways as an art, by the affiliation of apprentices to a master."

This does not mean that the disciple cannot overcome the master once, e.g. there are people who can speak better at a later time than their parents did. But for the time during which the disciple learns from the master, she/he must have the faith in the master's knowledge, otherwise this deep involvement cannot emerge. The master-apprentice relationship is also highly personal and involves all the other aspects of personalities of both the master and the apprentice. As this *'highly personal'* also means *'highly subjective'*, it is not suitable for our educational system in which the most important thing is to get rid of all subjective elements and to make everything measurable-controllable. This is why the master-apprentice relationship is out of fashion.

As we have seen so far, tacit knowledge is acquired tacitly. Does this imply that the explicit knowledge is acquired explicitly?

Russell (1948, pp. 109-118) classified the knowledge by its origin, according to which the knowledge is acquired with or without the intermediary role of words. Without words we personally perceive or we expect to perceive something in the immediate future (next moment); Russell calls this category non-verbal or sensational knowledge. We can perceive things and events around us; e.g. we can see a door slamming. Sometimes we anticipate what will happen, e.g. when we see the door slamming then its consequence, a loud bang, appears in our mind; if we close our eyes expecting the noise and someone stops the door, we will be surprised – we have known what is going to happen. All other knowledge is acquired by the inter-

mediation of words, that is to say from spoken words of someone, from a book, from a hypertext, etc. This category is the verbal or narrative knowledge.

The tacit knowledge may also increase when some explicit knowledge becomes tacit; and, similarly, the tacit knowledge may become explicit. The first is called *"internalization"* and the second is called *"articulation"*. (Nonaka, 1991, p. 4) An example for the first could be the already mentioned forgetting of the grammar rules (cf. Section 4.1.4) and for the second when one writes a report about a scientific result, which was perceived tacitly and, during the writing it is articulated. Accepting this, it can be argued that the tacit knowledge is always increased tacitly or by explicit knowledge becoming tacit; while the explicit knowledge is always increased explicitly or by some tacit knowledge becoming explicit.

When we think we use concepts and when we articulate knowledge, the concepts become words. (Russell, 1948, pp. 72-73)

"Language has two primary purposes, expression and communication… Music may be considered as a form of language in which emotion is divorced from information, while the telephone book gives information without emotion. But in ordinary speech both elements are usually present."

Articulation has got a significant role in de-subjectivization of knowledge.[1] The attempts to achieve this leave out of consideration the fact that the scientist has arrived at her/his results and thus to the new knowledge in intuitive, highly subjective mode. But these results are communicated using language, so if the language is de-personalized, de-subjectivized, in the second step the knowledge can become non-subjective. (Russell, 1948, pp. 18-19)

"It is true that education tries to depersonalise language, and with a certain measure of success… as your instruction proceeds, the world of words becomes more and more separated from the world of the senses; you acquire the art of using words correctly, as you might acquire the art of playing the fiddle; in the end you become

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[1] *It is usually called objectivization by those not understanding the conception of personal knowledge.*

such a virtuoso in the manipulation of phrases that you need hardly ever remember that words have meanings. You have then become completely a public character, and even your inmost thoughts are suitable for the encyclopaedia. But you can no longer hope to be a poet, and if you try to be a lover you will find your depersonalised language not very successful in generating the desired emotions. You have sacrificed expression to communication, and what you can communicate turns out to be abstract and dry."

Henceforth, the term **'learning'** will be used to indicate the type of learning done by the intermediation of words.

4.2.5. Aspect 4: Increase of Intuition, Skills, and Facts

As it was indicated that the focal knowledge belongs to the tacit domain and the subsidiary knowledge belongs to the explicit domain, it could be said that the first can be acquired in non-verbal manner while the second can be learned. But, as we shall see in this section, there are different ways of both verbal and non-verbal knowledge increase.

The subsidiary knowledge of facts is the most obvious type of learnable knowledge. We can verbally acquire second-hand facts, i.e. we are being told or we read of events experienced by someone else, and the rules of measuring the events. This appears to be non-subjective but often it would be very difficult for the learner to verify if it really is; often we acquire someone else's subjective statements presented as they are non-subjective facts. This kind of presentation is also much used in scientific articles (or, for instance in a PhD dissertation), although in these the sources are indicated so it could be checked where the statements come from. Of course, there might be a reference to another piece of literature in the source, so in reality it is unverifiable. For this reason we should try to use the original sources if at all possible.

The focal knowledge of facts is the prototype of Russell's previous non-verbal category; the focal facts are acquired by observation. Observation means experience, in which the observer does not interfere intentionally. It, of course, cannot be said that the observer will really never interfere with the observed event, see explanations

in Section 2.3, or just consider the previous example of the slamming door: the observer may be in the way of the door or change the direction of the wind by just standing in one place. Nevertheless, regarding the intention, an observer does not want to interfere with the observation.

The knowledge increase in case of subsidiary skills is a kind of learning by means of words. However, that is not the only way of acquiring the rules of a craft or of a social skill, as we shall see in the next section. The interesting relationship between the subsidiary and focal skills is that the subsidiary skills not necessarily improve the focal skills as we have seen in the case of driving; furthermore, a superfluous subsidiary skill may even destroy the focal skill. (cf. Section 4.1.4)

Focal skills are increased by practising. However, for mastering a skill, practising is not enough (de Bono, 1993, p. 4)

"A journalist who types with two fingers will still be typing with two fingers at the age of sixty. This is not for lack of typing practice. Practice in two-finger typing will serve only to make that person a better two-finger typist. Yet a short course in touch typing at a young age would have made that person a much better typist for all his or her life. It is the same with thinking. Practice is not enough."

This is what we do in elementary mathematics when we try to apply the learned formulas in textually described tasks. In these cases the external help actually increases exactly the missing part of subsidiary skill, which will enable us to perfect the focal skill. So, it actually remains that the focal skill is increased non-verbally and the subsidiary skill is increased verbally but these two forms interact. Besides, practising the focal skills may also be increased using the already mentioned intelligent imitation in the master-apprenticeship relation but it can also be reduced to an observing and a practising part. The practising of a skill and the previously used observation by which we increase our focal knowledge of facts are similar as both are experiences but, at the same time, they are different as the intention of the practising person is not to remain passive without influencing the event but to actively participate in it. This kind of knowledge increase is referred to as *"learning by doing"* by

Anzai and Simon ([1979](#)) and it is the suggested mode of knowledge increase for the *"reflective practitioner"* by Schön ([1983](#)).

The subsidiary part of intuition is the explanation, which consists of the rules of logic. They can be acquired verbally, much similarly to the rules of skills from the previous discussion. To use these rules we also need to practise them, though these will not lead to intuition but to a skill of using these rules. Thus we can learn to use inductive and deductive logic, and, most of all, the predicate calculus («if… then» rules). These types of formal logical reasoning are not what we use in focal intuition; the hunch is abductive (tacit reasoning). But to gain, at least, some understanding of how intuition works, it is a useful image to describe it as applying a number of rules tacitly at the same time.

It is probably clear from this short description that we know very little about the knowledge increase in case of focal intuition. We know only that the one having more (meaning the number of) and/or more complex cognitive schemata in a certain discipline will have a better sense for the essence. The hunch is an inner experience and we increase it with imitation and practising similarly to skills, but this practising is, in contrast to focal facts and skills, an inner experience. This can be the interpretation of Mandelbrot's assertion ([Gleick, 1988](#), p. 102):

"When I came in this game, there was a total absence of intuition. One had to create an intuition from scratch. Intuition as it was trained by the usual tools – the hand, the pencil, and the ruler – found these shapes quite monstrous and pathological. The old intuition was misleading. The first pictures were to me quite a surprise; then I would recognize some pictures from previous pictures, and so on. Intuition is not something that is given. I've trained my intuition to accept as obvious shapes which were initially rejected as absurd, and I find everyone else can do the same."

This is a good example of being aware that knowledge increase is resulting in enhanced intuition. The 'old intuition' is based on the 'old knowledge'; the new domain needs a new knowledge – a new intuition. However, the personal nature of intuition is very strong: a large proportion of knowledge seems to participate in it; that is the reason, that in the master-apprenticeship relation the disciple is not becoming a

(pale) copy of her/his master but an improved version of herself/himself, even though, for the time of her/his apprenticeship she/he is following the master's way (Polányi, 1964, p.15):

"He who would learn from a master by watching him must trust his example… Novices to the scientific profession are trained to share the ground on which their masters stand and to claim this ground for establishing their independence on it. The imitation of their masters teaches them to insist on their own originality, which may oppose part of the current teachings of science."

The master is indispensable in the case of focal intuition. The master is the example of imitation and she/he is also the one who can provide the small but necessary instructions to keep the disciple on the right track (this is a similar role to the typewriting teacher in case of skills from the previous example, only it is indefinitely more complex).

Now we can have a direct benefit from discussing the knowledge increase according to these different lines. There is an argument from those opposing the constructivist approach to perception (i.e. that what we see emerges from the interaction of reality and personal knowledge), actually they claim it to be a counter-example that falsifies the constructivist conception; it is based on the Müller-Lyer illusion. If you look at Figure 22, you will probably see the left arrow to be longer than the right one. The argument says that if you are *told* that the two arrows are of same length, you will still *see* the left arrow to be longer, so the knowledge (i.e. that they are of the same length) does not effect the perception.

http://eluzions.com/Pictures/Illusions
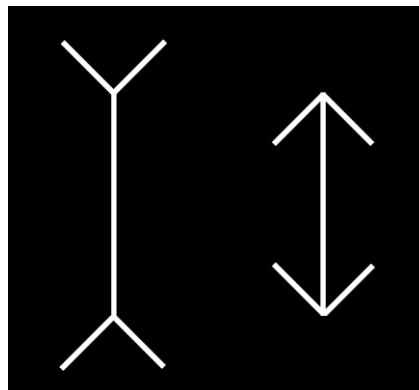
Figure 22: The Müller-Lyer illusion.

The argument is deceiving. The knowledge of the *fact* that the two arrows are of the same length does not affect the perception. The reason for this is that seeing the length of the arrows is not a factual knowledge but a *skill*. And it can easily be experienced that if one practises seeing the length of different arrows in such situations, one's perception will improve. Furthermore, it seems that 'seeing through' these illusion is a kind of skill, as the person practising several illusions becomes better at seeing the 'right picture' in cases of other illusions as well. The argument is thus simply not valid.

4.2.6. Aspect 5: Increasing Knowledge of "That", "How", "What", "Why"

Ryle ([1949](#), p. 27) considers knowledge of "that" consisting of facts and true propositions; where the facts have slightly different meaning than in Baracskai's (cf. Sections 4.1.5 and 4.2.5) model. This kind of knowledge we can obviously acquire verbally, in other words we learn it.

Ryle ([ibid](#), p. 29) emphasizes the unclear nature of the concept of knowledge increase:

"We speak of learning how to play an instrument as well as of learning that something is the case; of finding out how to prune trees as well as of finding out that Romans had a camp in a certain place; of forgetting how to tie a reef-knot as well as of forgetting that German for «knife» is «Messer». We can wonder how as well as wonder whether."

This contrasts the knowledge increase of "that" and "how" type. There is, however, an interesting line of argument, according to which the two types of knowledge may overlap exactly in terms of knowledge increase. Ryle ([ibid](#), 40-41) describes a person learning how to play chess in two different possible ways. Usually the chess player learns the basics by receiving explicit instructions about the rules; she/he learns them by heart and can cite them on demand. During her/his first games she/he usually has to go over them aloud or in her/his mind, sometimes asking how the rules should be applied in a particular situation. Gradually she/he becomes able to fol-

low/apply the rules without thinking of them. This applies to both the positive and negative knowledge; the chess player makes only the permitted moves and avoids the forbidden ones. At this stage the chess-learner usually loses her/his ability to cite the rules. According to the other description, one may also learn chess without ever hearing or reading about the rules. One may observe how others play; starting to play observing which of her/his moves are accepted and which are rejected. Gradually one may pick up the art of playing correctly without ever being able to propound the rules.

The first type of learning chess is the increase of the knowledge of "that" but only at the beginning, until the pupil learns the rules of chess. Later in the first type, and all along in the second type, the knowledge of "how" is increased; furthermore, the knowledge of "that" is gradually converted into knowledge of "how" as the pupil becomes unable to cite the rules anymore. The second type of increasing the knowledge of chess is how we acquire most of our common sense, e.g. our mother tongue. Here is a personal example of how this second type of knowledge increase can consciously applied in mastering additional language.

> *In my primary and secondary school I have been learning English as a foreign language, the same way as it is usually taught in most of the schools – by memorizing words and grammatical rules. This was almost all of my knowledge of English before I had moved to Glasgow, actually I have spent only one week previously in an English speaking environment. Of course I was reading scientific articles and acquired the necessary professional vocabulary – but this did not contribute much to the speaking and writing better. My knowledge of English was totally a textbook-style English.*
>
> *Just before moving to Glasgow I started to read in English – the same way as children do; actually I started with books for 7-11, then for 12-14, and so on, in less than six months I was reading Polányi and Russell. During the first year of my stay in Glasgow I have read over twelve thousand pages apart from the necessary readings for my work.*

> *The intention was to acquire English in a similar way as children do; thus, I did not use any dictionary, if I remembered to ask someone a word or phrase or how to use a word or a phrase, I asked. Usually I forgot. Of course I also had to use English in my day-to-day activities. I did not feel that I spoke any better than before but I noticed that others understood me better, I understood others better, and my spell checker underlined less and less.*

The increase of knowledge of "why" and "what" is similar to the increase of "how" knowledge. There is, however, an important difference: the increase of "how" knowledge is gradual, while the other two knowledge types seem not to increase for long time, i.e. the knowledge increase is not manifest. This requires a lot of patience from the person increasing her/his knowledge of these kinds and from the environment as well.

The non-manifest nature of increase of "why" and "what" knowledge is one of the reasons that these types of knowledge increase virtually always happen in master-apprentice relationship. Only the master can recognize the almost unnoticeable signs of the increased knowledge of the apprentice. Later, at once, the apprentice shows a great leap in performance, often surprising everybody, including herself/himself. Only not the master.

Both, the "why" and the "what" knowledge increase gradually but, as they are parts of deep knowledge, the performance becomes manifest only at later (higher) stage. Deep knowledge (see in next section) means that it consists of cognitive schemata of high complexity. Both these types of knowledge build on previously acquired knowledge, often of other types. In the cooking example in Section 4.1.6 the "why" knowledge was explained as knowledge of why a particular ingredient is put into the food. Increase of this type of knowledge involves parts of "that", "how", and "what" types knowledge increased. The cook increases his knowledge of "why" about that ingredient by increasing "that" knowledge about the features of the ingredient, "how" knowledge of different uses of the ingredient, and "what" knowledge about the occasions the food is usually prepared for.

The "what" knowledge is in all these aspects similar to the "why" knowledge. The leader increases her/his knowledge about what to do, where to lead the organization by also increasing her/his "that" knowledge of events in the market, her/his "how" knowledge of the behaviour of the competitors, and her/his "why" knowledge about the nature of the environment of the organization.

These similarities of the "why" and "what" knowledge became clear by examining the increase of these knowledge types. Probably here we can also find the reason, why Gardner (1995, p. 11 ff) finds similarity between problem solver and leader: the great problem solver leads the discipline while the great leader leads a social construct, e.g. a business organization or a nation. The analysis of "why" and "what" knowledge also explains why the knowledge increase is to be led not managed; it is "what" knowledge to choose direction for knowledge increase.

The necessity of master-apprentice relationship in case of "why" and "what" knowledge is probably also clear from this brief description; a more detailed account is given in our recent book. (Baracskai-Velencei-Dörfler, 2005)

The last direct benefit of the previous examination is that we have a clear account now of why the concept of knowledge presupposes the concept of knowledge increase (which in turn presupposes the concept of knowledge, of course) as previously cited from Ryle (see Section 4.1.6) and from Davenport and Prusak (see Section 4.1.1).

4.2.7.   Aspect 6: Representations of Knowledge Increase

Knowledge increase in terms of knowledge representations can be described as the representing world becoming richer. The purpose of science can be described in these terms as enriching the representing world to achieve better correspondence to the represented world.

The representations of knowledge, as it was said previously (cf. Section 4.1.7) are based on the types of knowledge from the previous section. The propositional knowledge representations correspond to "that" knowledge, thus the increase of

knowledge in propositional representation is the same as the increase of "that" knowledge. But we can also discover additional details by examining the different models of propositional representations.

The easiest description is to consider the increase of knowledge in propositional representation as adding new facts or statements. However, if we consider the model of semantic networks, we can think of adding new concepts (symbols) and new relations. If we think of the meaning of a concept in connection with the pattern of its relationships with other concepts, the picture becomes richer, i.e. by adding a new concept and/or new relationships the meaning of existing concepts may be modified, just as it was described in Section 4.2.2 about the process of knowledge increase. We also must not forget that the representational system was said to be consisting of the representation and the processes operating upon them; thus the representational system may be changed also by changing these procedures, even if the representation remains the same.

The knowledge increase in case of analogical representations, if it is about the models of objects, happens by seeing the objects and their transformations – to take a trivial case. However, there are less trivial cases as well. Nikola Tesla was well-known for developing his inventions 'in his mind' and building new machines without ever committing his ideas to paper in forms of blueprints. This is, of course, an extreme case, but every inventor creates a model in her/his mind first before putting it on paper, and probably improving it. This means that using mental operations that operate on analogical representations, the problem solver increases her/his knowledge without external input. This is an important finding, even though the knowledge increase of the problem solver is not investigated in the present dissertation. However, we may also acquire some new procedure operating on the analogical representation or some new view or a new transformation of an existing mental model, which increases our knowledge in that analogical representation.

A mental model may also evolve as result of a number of statements acquired, i.e. we acquire propositional knowledge, and this increased propositional knowledge results in emerging analogical representation. E.g. an object and how it works can be

described in statements invoking the mental model of the object and/or its transformations.

The first examination of knowledge increase in analogical representational system applies for figurative mental models only, the second for both figurative and abstract ones. Is there any other way to increase our knowledge of abstract mental models? Yes, there is. In master-apprentice relationship the master often uses parables to describe some abstract mental model of high complexity, but actually she/he does not describe the model itself, but the parable somehow invokes the mental model. A similar case for figurative mental models would be when we hear a song or a poem about a landscape, the song or the poem does not actually describe the landscape in detail but still invokes the mental model of it. Yet another way of knowledge increase in analogical representational systems is enlightenment, when a mental model suddenly emerges from the existing knowledge.

Two versions of procedural representations were distinguished in Section 4.1.7, the 'real' procedural representations and those having an underlying propositional representation. As the procedural representation corresponds to "how" knowledge, in terms of knowledge increase, the two versions of propositional representation correspond to the two different ways of learning chess from the previous section. Although it is true that most of the "how" knowledge that may be acquired verbally can also be acquired non-verbally (usually it takes somewhat longer), the opposite is not true, and this can be understand from the two versions of procedural representations.

Davenport and Prusak (2000, p. 71) report of Prusak's attempt to learn hitting (baseball) from Ted Williams's book. His performance actually improved somewhat but, years later, he attributes this improvement to his increased self-confidence. He claims that baseball cannot be taught through books. This can be explained if we suppose that hitting in baseball is the 'real' kind of procedural representation. Rumelhart and Norman (1988, p. 564) described the processes stored in 'real' sense of procedural representations being able to incorporate new knowledge within the same structure. To this type of knowledge representation, apply everything said about the acquisition of focal skills.

We can also think of the processes that operate upon different knowledge representations as the processes stored in real sense of procedural representations. This offers an explanation to why e.g. de Bono (1993, p. 6) says that thinking is a skill:

"The relationship between intelligence and thinking is like that between a car and the driver of that car. A powerful car may be driven badly. A less powerful car may be driven well. The power of the car is the potential of the car just as intelligence is the potential of the mind. The skill of the car driver determines how the power of the car is used. The skill of the thinker determines how intelligence is used."

In terms of knowledge representations we could say that the knowledge representations are the power of the car and the processes operating upon them are the skill of the driver – these processes are the processes of thinking.

The distributed representations can be understood only through knowledge increase. The opposite of distributed representation conception is the conception of local representations. If our knowledge representations are local, the new knowledge would always be added to the corresponding part of existing knowledge and this conception is difficult to maintain as the new knowledge usually connects to multiple components of existing knowledge. According to conception of distributed representations, the new knowledge is added to the whole of the existing knowledge and it is dispersed everywhere in personal knowledge with no specific location. Probably thinking in terms of physical space for the knowledge is not a good analogy at all. Probably the knowledge increase also has an effect similar to the increase of spatial dimensions if the former analogy is to be held – and this is very difficult to imagine.

4.2.8. Aspect 7: Knowledge Increase at Different Levels

The knowledge levels in Section 4.1.8 were described by the number of cognitive schemata. It was also stated that the (grand)master level also differs qualitatively, because the cognitive schemata are on this level of high complexity. From the viewpoint of knowledge increase, the lower three levels do not differ substantially, although, on higher levels there are more schemata or groups of schemata to which the

new knowledge can be connected. By contrast, the knowledge increase of (grand)master fundamentally differs from these three.

How can one achieve the grand(master) level of knowledge? According to Mérő (1990, pp. 116-118) and Baracskai (1998, pp. 50-52) it takes 8-10 years to get from novice to (grand)master level. This means that each new level can be achieved (increase in number of cognitive schemata by one order of magnitude) in 2-3 years. (Figure 23, the two graphs) It takes 2-3 years just not for everybody but only to the ones gifted in the particular discipline. The problem of 'gift' is very important but it is left for another investigation (e.g. a 'model of talent' could be developed as a further component model for the MLA); the present research does not deal with it, rather, it is focused on talented individuals only.

If the (grand)master changes her/his discipline, she/he is beginning from an advanced level, while all the others are necessarily beginners; the reason for this is that the high-level meta-schemata of the (grand)master are of high complexity and thus can be, to some extent, applied in the new discipline. (Figure 23, arrows)
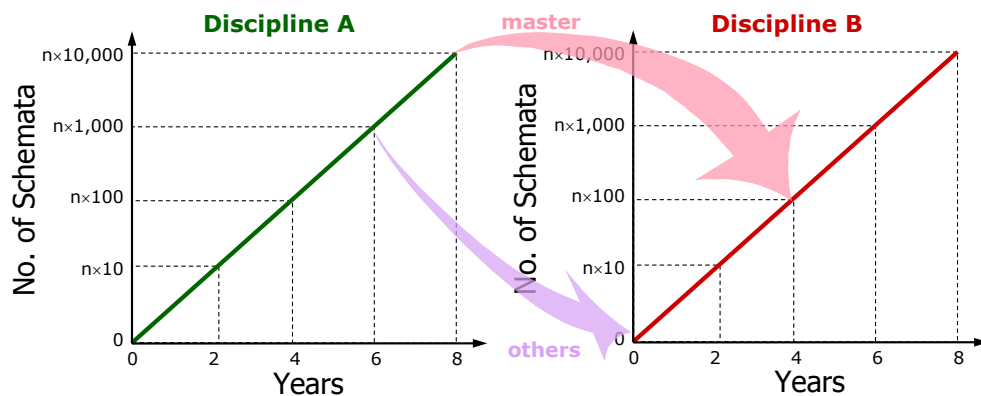
Source: Baracskai (1998, p. 51)

Figure 23: Changing the discipline.

The difference in knowledge increase of the (grand)master and the others can be described in terms of cognitive schemata. (Figure 24) On sub-master levels new knowledge is received by gluing the new schemata to the existing ones, as described in Section 4.2.2. The existing and new schemata will form an ad-hoc structure, and when achieving a deep understanding a meta-schema evolves. To acquire the same new knowledge, the master of a related discipline:

- needs fewer new schemata to acquire the same knowledge,

- glues these new schemata to an existing meta-schema, at the same time this meta-schema

- transforms into a new one, incorporating the 'old' meta-schema, the new schemata, and somehow the new meta-schema even extends beyond all these.

For the (grand)master some new schemata may be superfluous, even though they can be useful to the levels below. Using the markings from Figure 24:

- The advanced learner will understand some details: $z_1 \oplus x_1 \to y_1$ and $x_2 \oplus x_3 \to y_2$,

- though to her/him the whole does not emerge: $y_1 \oplus y_2 \neq Y$.

- The master assembles the whole using fewer schemata and these are enough for the emergence of the whole: $z_1 \oplus x_2 \oplus x_3 \to Y$,

- the rest of the schemata are unworthy to her/him: $x_1 = 0$.
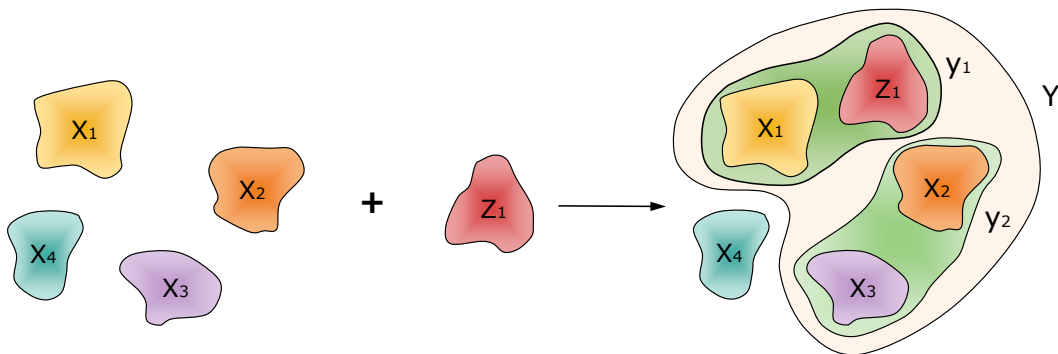
Figure 24: Knowledge increase of the master and of the advanced.

This difference is quite easy to understand, to know it as a fact – a "that" knowledge – but it is very different to actually experience it directly, and to have this experience from a sub-master level.

When I became a disciple of my master Zoltán Baracskai, I soon started to do some work in the area of quality management. After about one year I was walking to visit my master and I was thinking about the quality of

things, how a Barbie doll or an atomic bomb can be of good quality. And all of a sudden I understood: there are two different types of quality, the quality according to rationality of goals and the quality according to rationality of values. I told Baracskai about my idea and he liked it a lot. I spent my spare time for next several months trying to put this on paper. First I thought it should be the fifth one of Shoji Shiba's levels of quality, but I realized that there were not only vicious things of good quality but also good things of poor quality. Then I tried putting the two kinds of quality as two pyramids, one standing and the other upside down, but I failed to systematize my examples. Finally I asked my master for advice.

He found the solution in less than two minutes. I positively knew that he had never worked in the field of quality management; he should have known only how much I had told him… Later I understood. I experienced the difference between the knowledge increase of the master and of the advanced student. Quality management was a new territory for both of us; after one year I was still a beginner in the field. The master used his high-level meta-schemata. To be honest, at that time, this experience felt terrible; still, I ended up with a conference paper.

The differences between the levels of personal knowledge are usually described by the number of cognitive schemata, and thus the discipline is described similarly. However, the complexity of schemata is also important. It has several consequences for the individual increasing her/his personal knowledge, and for the disciplines as well. Some disciplines consist of more complex schemata, some of less complex ones. This indicates the depth of the discipline. 'Go' is, for instance, deeper discipline than chess (Mérő, 1990, pp. 153-155); thus in chess the beginner will more often win against the advanced than in 'go'.[1] This may be a reason for the great popularity of soccer: it is very shallow (actually it does not qualify for a discipline, at best,

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[1] *The deeper the discipline, the bigger the difference is between the knowledge at different levels. The difference in the number of schemata between the levels is the same but, as the schemata are more complex in the deeper discipline, the difference in the complexity of knowledge is bigger if the discipline is deeper.*

it is an underdeveloped one), so, the weaker team has considerable chance for winning. Another consequence for disciples in deep disciplines is that their performance improves slower than in a shallower discipline.

The specialities of the knowledge increase on (grand)master level were only investigated to exclude the (grand)master from the further examination. The high-level meta-schemata of the (grand)master are capable of extending surprisingly beyond the existing and new knowledge, as described in the present section, which would much complicate the model. Another reason is that it is not easy to find (grand)masters for observation and they also show great variety – we could probably say that each is unique. The present investigation of knowledge increase is thus focused on the expert level; one direction of the further research will be on extension of the model to cover the (grand)master level as well.

4.2.9. Aspect 8: Value of Knowledge Increase

The value of knowledge was introduced in Section 4.1.9 using two levels, the judgment about a particular knowledge and the meta-judgment about the knowledge in general; both levels were introduced from the viewpoint of the individual and from the viewpoint of the organization. There were various difficulties described about these judgments. The situation is further complicated if we want to consider the knowledge increase. First, a simplification is made, instead of the knowledge increase, the new knowledge will be considered. As it was already indicated that one of the troubles with judging the knowledge is that we should know everything about its future use as well, this does not introduce a new limitation.

When judging the new knowledge we want to compare it to our individual value system (similarly in case of organizational value system). We face another difficulty here: we could compare new knowledge against our value systems only after absorbing it but we want to judge it in advance as we are to decide whether to acquire it or not. Thus we are to take judgment instantly, and this judgment can be refined later on, during the process of knowledge increase or once it is finished. It must be noted that the instant judgment does not occur about the new knowledge but about a picture

that we form about the new knowledge using existing knowledge, which does not contain the new knowledge.

For the picture of the new knowledge, it is important who does paint it. These are all sources of subjectivity. There are two roles involved in painting the picture: the person who recommends the new knowledge (e.g. the mentor, an advisor) is the primary source and the person, who the new knowledge comes from (it can be the lecturer, the author of the book, etc.), is the secondary source. The two roles may be carried by the same person. We have all the reasons to assume that, if we think highly of a person, we will also think highly of the new knowledge mediated and/or recommended by her/him. On the receiving end of the picture, it is important that we have different existing knowledge, thus the same picture will have different meaning to everybody.

This subjective judgment about the new knowledge leads us to the only viable strategy for knowledge increase in an organization. There is a vast amount of knowledge available in the environment and – not last thanks to the internet – the most recent can be easily accessed. It is clear that no organization can afford to let its members learn everything – such organization would stop working and would be bankrupt in no time. The organization, which would wait for validated knowledge would always be late; it would start considering the new knowledge when its competitors would already be using it. Therefore, the only possible source of the strategy is the subjective judgment based on the picture about the new knowledge. The important question is: whose subjective judgment? Of course, the judgment of the expert of the domain. This is another reason why this investigation is focused on the expert. The MLW is constructed to provide support to this type of strategy.

For deeper enquiry into this process we need to define grades, which indicate the judgments and the meta-judgments of the personal and organizational value systems. For judgments of the personal value system, the values are arbitrarily chosen, intended to be intuitively obvious – and they also fit the observations. Personal judgment is:

- *«promising»*, if we have high expectations towards it (e.g. if one wants to learn about the new achievements about quarks and one is genuinely interested in quantum physics);

- *«neutral»*, if we do not care about it; and

- *«ominous»*, if we are afraid of it for some positive or putative reason (e.g. a heavy smoker usually would not like to know what effects smoking has on her/his lungs).

The values of the organizational judgment are less arbitrarily chosen, as it was said that, for organizations, knowledge is of survival value, and thus Bertalanffy's (1981, p. 17) terminology is adopted for describing the grades. Organizational judgment is:

- *«useful»*, if the new knowledge seems to get the organization some benefit in its struggle for existence (e.g. a new knowledge on production process may result in cost reduction or quality improvement or shorter time to market);

- *«indifferent»*, if it is neither good nor bad, does not affect its survival (e.g. a new knowledge on genetics usually does not effect a light bulb producing company); and

- *«harmful»*, if it is thought to be dangerous to the organization (this last may not sound trivial, and indeed, in many organizations we will not find this category; but think, e.g., of an army, where soldiers have learned how the light uranium-coated munitions affect health).

Similarly to the previous, grades of meta-judgments need to be defined. Instead of defining the grades of meta-judgments directly, it will be done along two factors in which the meta-judgments manifest themselves. This has an advantage that these behavioural patterns are easier to observe in real-life situations. The two factors are interrelated and they are manifested in situations in interaction with the other party (for the individual the organization is the other party and the other way around); one is the *influence* (trying to influence the other party to change its judgment) and the

other is the *resistance* (one part resisting the influence of the other party to change ones judgment). The values here are again arbitrarily chosen, aiming to be intuitively obvious, and they fit the observations:

- The highest value of personal influence is to *«raise voice»* if disagreeing with the organizational judgment; the moderate one is to *«set examples»* (behavioural patterns) to others; and the individual may also *«withdraw»*, i.e. to give up influencing.

- The personal resistance can be described with values *«no price»*, *«grudgingly»*, and *«ungrudgingly»*, i.e. these are how the person changes her/his judgment.

- Organizational influence may be to *«support»*, to *«tolerate»* or to *«forbid»* the new knowledge. Some organizations will consider it a waste to spend any time with a new knowledge, which is not useful, therefore it will be forbidden; some other organization may tolerate even the harmful new knowledge, considering the learning itself to be important – according to the knowledge orientation of the organization as described in Section 4.1.9.

- The organizational resistance here is described by two values only; it may be *«rigid»* or *«flexible»*.

Alternative number of values or different names could have been used to describe the introduced aspects, and, we may use different values in particular cases; the important part is the thinking process. We must not forget in particular cases that the same person will behave differently (have different meta-judgments) as member of different organizations, and the organizational meta-judgment of the same knowledge may not be the same for all members of the organization.

4.3. Chapter Summary – Dimensions of the Inquiry

This subchapter is a chapter summary but apart from summarizing what has previously been said in the two subchapters, it also makes some additions; namely the

various typologies that were introduced are here put into relation. Also this subchapter indicates the dimensions along which the resulting models are developed in Chapters 6 and 7.

At the beginnings of the two subchapters it was found that knowledge and knowledge increase do not easily give to strict definition in the sense of Section 2.7. After the examination done in the two subchapters this is even clearer – there are lots of different things that belong to knowledge and lots of different things going on in knowledge increase. Although it is not a definition, what was described during the examination can be considered as a very detailed description of knowledge and knowledge increase.

Knowledge was described as a system, elements of which are the cognitive schemata. There are relations between cognitive schemata and they form subsystems with inner structure. Meta-schemata correspond to these subsystems. The process of knowledge increase was described as acquisition of a new cognitive schema; the new schema is not simply added to the existing ones, it may kick out some of the existing schemata, break or modify existing relationships and creating new ones, and it may modify the existing structures too.

Knowledge and knowledge increase are considered to be personal in the present inquiry; the existence of organizational knowledge and thus the increase of organizational knowledge are argued non-existent in the sense of personal. Of course organizational knowledge capital is acknowledged but it is not investigated in the present research.

Four sections in each subchapter dealt with knowledge typologies, from the viewpoints of knowledge and knowledge increase respectively. These typologies are synthesized here, i.e. their relations are described. The shortest summary of these typologies can be found in Table 2, which is followed by more detailed explanations. It is also indicated, in both the table and in the descriptions, how each of the discussed knowledge types can be increased. The arrows at the bottom of the table and the thick lines indicate the columns on which this dissertation focuses.

Table 2: Knowledge typologies synthesized.

Sorts	Facts		Skills		Intuition	
	PERSONAL KNOWLEDGE					
Focal-subsidiary	Focal facts	Subsidiary facts	Focal skills	Subsidiary skills	Focal intuition	Subsidiary intuition
Tacit-explicit	Tacit	Explicit	Tacit	Explicit	Tacit	Explicit
That/How/Why/What		"That"	"How"	"That"	"What" / "Why"	"That"
Representations	Analogical	Propositional	Procedural	Propositional	Analogical	Propositional
Knowledge increase	Experiencing events, internalization	Learning, articulation	Practising, internalization	Learning, articulation	Inner experience, internalization	Learning, articulation

Tacit and explicit knowledge cannot only be increased the trivial way, i.e. tacit knowledge tacitly (without words) and explicit knowledge explicitly (using words, i.e. by learning) but also by passing of some knowledge from the tacit domain to the explicit or the other way around; the first is called articulation the second internalization. Common sense and special knowledge were also contrasted in Section 4.1.4; it was accepted that common sense is highly complex and belongs to tacit domain (of course special knowledge is usually also partly tacit) and it was excluded from further investigation.

Focal knowledge is tacit and subsidiary knowledge is explicit, and in this respect what has been said about the tacit and explicit knowledge also applies here. However, there are different ways of tacitly acquiring knowledge. Subsidiary facts are increased by learning and focal facts by experiencing events. Subsidiary skills are also learned but it was also shown that we may acquire rules of skills by observing masters for long time. Focal skills are practised. Subsidiary intuition is, again, acquired by learning and focal intuition by inner experiencing. Thus we have identified three different types of tacit learning: experiencing events, practising, and inner experience.

Knowledge of "that" is similar to the subsidiary knowledge so it is explicit and is increased by learning. Knowledge of "how" corresponds to focal skills, which are tacit and are to be practised. Knowledge of "what" and "why" both belong to focal intuition, thus they are also tacit and are increased by inner experiencing. Those parts of knowledge of "how", "what", and "why", which can be reduced to knowledge of "that", belong to subsidiary knowledge. This model does not seem to cover the focal facts.

Propositional representations correspond to knowledge of "that" and thus to subsidiary knowledge and to explicit knowledge; knowledge increase in propositional representations happens by learning. The same is true for the part of procedural knowledge behind which there is a propositional representation, more precisely it belongs to subsidiary skills. The other part of procedural representation corresponds to knowledge of "how" and thus to focal skills which is tacit and should be practised. Images or analogical representations cover focal facts and focal intuition, so somewhat more than the knowledge of "what" and "why", they are tacit and are increased by experiencing event and inner experiencing.

Four levels of knowledge are used in the present dissertation, namely the beginner, the advanced, the expert, and the (grand)master. It was shown that both the knowledge and the knowledge increase of the (grand)master fundamentally differ from the others', and thus the (grand)master is excluded from the results of the research, and the focus is on the expert. However, observing the (grand)master had a significant impact during the research and even provided better understanding of knowledge at other levels by identifying the contrasts.

The value of knowledge was examined in terms of value judgments on the basis of individual and organizational value systems. There were actually two kinds of value judgments; the first is called judgment the second meta-judgment. The value of knowledge increase is substituted by the value of new knowledge, which is considered not to limit the validity of the model.

Knowledge can be examined along a variety of dimensions; in Figure 25 different plains correspond to different dimensions, the tube corresponds to knowledge. For

instance, on a philosophical plane we can examine if certain piece of knowledge belongs to truths of facts or to truths of mind. The truths of fact can be only found in deterministic processes, but we could try to create truth-conceptions for the higher-level processes as well. It could be started with examination if the probability-logic satisfies the stochastic processes (it seems to be trivial, though it is not so). On the plane of logic we could examine e.g. if the bivalent logic is appropriate to describe a piece of knowledge, or how it can be handled with probabilistic logic, or how it behaves in the domain of trance-logic (Mérő, 1990, pp. 23-25).
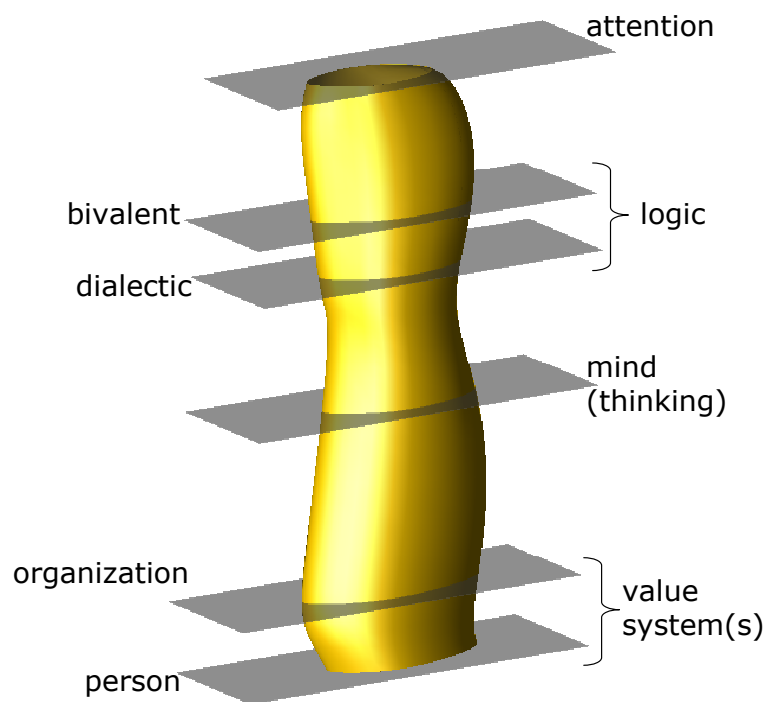
Figure 25: Plains for examining knowledge.

In the present investigation knowledge is examined using three dimensions:

1. The plane of value systems is further divided into two sub-planes; one is dedicated to personal and one to organizational value system. On this plane the MLW is created.

2. The plane of human mind, i.e. thinking; most of what has been discussed in this chapter is used on this plane to create the MLC.

3. The plane of attention is examined as a single plane for now but it will also be divided into two sub-planes during the process; namely the motivational and the cognitive factors of attention will be considered. MA is created on this plane.

The three models are integrated into a last one, into the MLA. This corresponds to integrating the three planes into a single one. However, the research has been conducted by developing the three models in parallel, and thus it is reasonable to consider them as three different dimensions – three different planes.

5. Problem Formulation

> *"Yü, how boorish you are. Where a gentleman is ig-*
> *norant, one would expect him not to offer any opinion.*
> *When names are not correct, what is said will not*
> *sound reasonable; when what is said does not sound*
> *reasonable, affairs will not culminate in success…"*
>
> *Kung-fu ce (Confucius)[1]*

Having examined the three outer circles of the spiral of discussion from Appendix 2 (the top three levels of the 'drilling hole' on Figure 3), we arrive at the 'nexus', the problem itself (represented as the fourth level from the top in Figure 3 and all that is within the "Boundaries" in Appendix 2). Thus now the problem can be explicitly formulated more precisely than it was described in the Introduction. This is done chapter in three steps: First, the way of getting to the problem statement is described linking back to the process of scientific problem solving described in Section 2.8. Then, the boundaries, that were identified throughout the previous three chapters, are briefly summarized; only to have them collected at one place in case that there is a need at some point later to check the validity of the results. Finally, the problem is stated in a positive form; some additional simplifications are introduced for the forthcoming modelling stage; and a typology of results is introduced the results of the dissertation are classified according to this typology, to provide some preliminary understanding of the models that are described in the next two chapters.

5.1. Approaching the Problem

To clarify the approach to the problem and the way of getting to the problem statement, which is the aim of this section, the process of scientific problem solving from Section 2.8 is revisited. There was a conception of scientific problem solving introduced in three phases in Section 2.8; this conception was used in this research.

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[1] *Confucius (ca 500 BC) The Analects of Confucius, Book 13. Retrieved 17/10/2005 from* http://afpc.asso.fr/wengu/wg/wengu.php?l=Lunyu&no=320 *(The "gentleman" in the quota-tion should be understood as 'educated' or 'cultivated'.)*

The essence of this conception was to identify component problems first and try to shed light on them; some will be solved, some will be abandoned, and some will be further divided. The findings about the component problems together (more precisely not necessarily all of the component problems, maybe only some of them) form a result, and when it is almost formed, we can also formulate the problem. This process will be here described more precisely.

The first choice to make in scientific problem solving is about the problem domain. What criteria can be used to make this choice? It has been argued in Section 2.8, based on Kuhn and Einstein, that the usefulness or the importance of the problem should not be a taken into consideration. Based on Pólya it can be argued that there are two criteria:[1] (1) the problem solver has to have sufficient knowledge of the domain to have a chance creating something new; (2) the problem solver has to be genuinely interested in the problem domain, so that she/he can make use, apart from her/his intellect, of her/his passions, emotions, etc. Using these two criteria, 'knowledge increase' was chosen for the problem domain. (Figure 26[2])
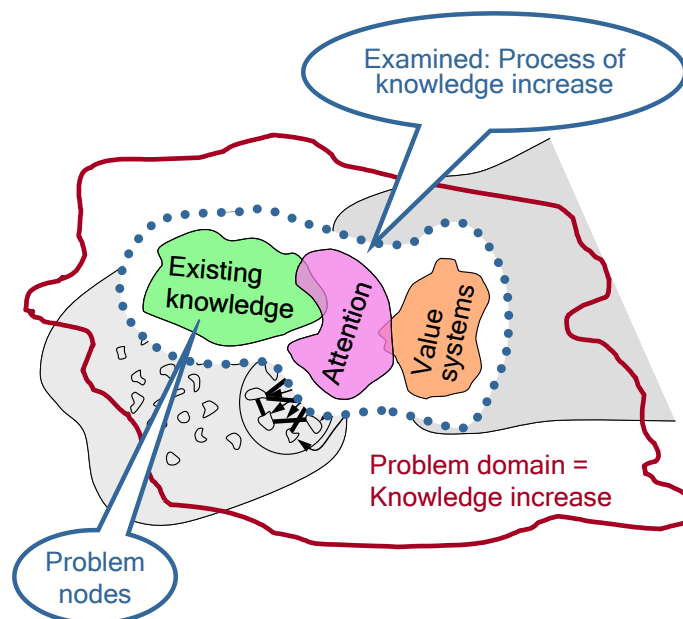
Source: Adapted from Baracskai-Velencei-Dörfler ([2005](#), p. 46)

Figure 26: Problem domain, problem nodes, and what is examined.

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[1] *There is actually a third criterion: the financial background has to be provided. However, this criterion did not play role in the present research.*

[2] *The grey shape behind the problem domain is the knowledge increase from Figure 21a.*

The second choice is to decide what we want to examine. Here it can be suggested to choose a process. ([Baracskai-Velencei-Dörfler, 2005,](#) p. 45 ff) This assertion needs a bit more detailed explanation: What alternatives do we have? We could choose an element (a concept) from the problem domain; in this research it could mean choosing e.g. elements of knowledge (cognitive schemata). The elements are, however, too a narrow topic for a research – we would inevitably end up in philosophy, as it is probably obvious from the beginning of Chapter 4. On the other hand, we could also choose a larger piece, e.g. the whole knowledge, which is, by contrast, too large; a research, which could be completed in reasonable time, would be too shallow and a decent research would last for decades. A process was therefore chosen for the present research, and it is the 'process of knowledge increase'. (See again Figure 26)

The next choice is about the component problems; there were five initial component problems described near the end of Section 2.8. However, when we first identified the component problems they did not appear in formulated form, rather, like gravitational points (points with a field of attraction of uncertain size around them), i.e. we recognize that there is something but it is not clear yet where it is and what belongs to it. Therefore we may call them problem nodes at this stage. ([Baracskai-Velencei-Dörfler, op.cit.](#)) Later they will evolve into component problems, which are meaningful wholes in themselves. Instead of repeating the initial component problems from Section 2.8, here the final component problems are given; there are three of them (see Figure 26 and Figure 27):

- It is not known, how the existing knowledge affects the process of knowledge increase.

- It is not known, how the individual and organizational value systems affect the process of knowledge increase.

- It is not known, how the attention affects the process of knowledge increase.

One model will correspond to each component problem in the main results, and they will be integrated into a fourth one, which corresponds to the problem; but this

will come later. To arrive at the models, we should get back to the problem nodes, to follow what happens to them. Once we have identified the problem nodes, the trans-disciplinary work begins; this is what happened in the previous three chapters. It is illustrated on Figure 27 with the line that connects some pieces of knowledge, be-liefs, tools, models, conceptions, or approaches that are borrowed from the neighbouring disciplines (Figure 27 indicates those neighbouring disciplines that were visited in this research). During this trans-disciplinary research several things shall happen: (1) the problem nodes evolve into component problems, i.e. now we can describe them; (2) the initial ones transform into the final ones (by abandoning some and dividing others), as this dissertation arrived from the five initial compo-nents (Section 2.8) to the final three ones described above; (3) the problem gradually gets formulated. Having a look at Figure 27 we can see that the problem actually covers a somewhat larger area than the component problems. E.g. the motivation is not covered by the component problems, which may be why it initially seems some-how unfit among the topics discussed in Chapter 3, but during the modelling in Chapters 6 and 7 it will be of great importance.
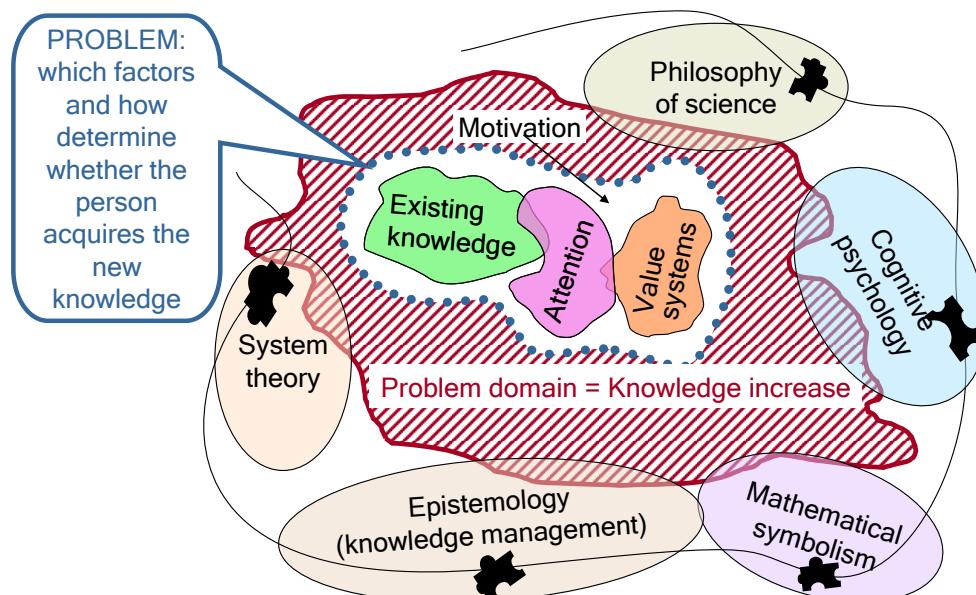
Source: Adapted from Baracskai-Velencei-Dörfler (2005, p. 51)

Figure 27: What is in and what is out?

During the process the problem was gradually formulated by making a series of decisions regarding what to include into the investigation and what to omit. This is

often formulated in negative terms, i.e. it is often easier to say what is excluded, and what remains is included; that is why in the previous three chapters it was often indicated that something is excluded from the further investigation. The following section gives a short overview of the boundaries that were identified during the research, indicating what is excluded. The positive problem statement remains for the last section of this chapter.

5.2. Boundaries of the Problem

The boundaries of the problem, as in the case of any scientific problem, are fuzzy. During the investigation some boundaries became sharp. The validity of the results presented in this dissertation is claimed only within these recognized boundaries, although some results may be valid beyond these boundaries, but their validity is not examined in those domains. In the Conclusions these will be indicated as possible research directions. This section summarizes the boundaries recognized during the investigation.

During the learning process, new component knowledge (a cognitive schema) is absorbed (connected to existing knowledge). (Section 4.2.2) This schema passes from STM to LTM. (Section 3.4) This process is little known and it is also not investigated in this thesis. Instead of the actual process, states (i.e. knowledge before and after absorbing the new schema) are examined, thus the resulting model is quasi-static. The conditions, under which the new schema is absorbed as well as the speed of the absorption, are investigated. (Sections 3.4 and 6.3)

In modelling motivational factors of attention, only one dimension of the social needs is considered, namely the role of love. For a full description it would also be important to map the other dimensions (the economical and the political dimensions; the influence of money and power) and clarify their roles. This is a topic of a complete separate research, which will probably be carried out some time in the future. (See Section 3.6 and the Conclusions)

Only the knowledge increase that happens by absorption of new knowledge is considered; here it is called learning. (See Section 4.2.2) By doing so the other forms of knowledge increase, namely 'inner experiencing' (e.g. when the scientist, as metaphor for the problem solver, increases her/his knowledge by rearranging her/his existing knowledge)[1], experiencing of events (the knowledge increase of the observer), and practising (the way of acquiring skills). This was summarized for the used knowledge typologies in Subchapter 4.3.

The source of new knowledge is called available knowledge, and it was defined in Section 4.2.2 as knowledge admitted by the paradigm. Therefore, to keep the model simple, the filter-effect of the paradigm is not separately modelled. In a multi-paradigmatic environment (i.e. where multiple paradigms are allowed, such as in universities) it would make sense to model the effect of the paradigm.

The new knowledge, as discussed in this dissertation, is always received from a mediator. As it was shown in Section 4.2.9, from the viewpoint of the value judgments, it is very important how the learner sees the new knowledge (e.g. how important or how useful it is), and the mediator plays important role in the formation of this picture. The mediator's effect on knowledge increase is interesting, but in the present research it is not investigated.

Starting from Polányi's approach of personal knowledge (Sections 4.1.3 and 4.2.3), the organizational knowledge is asserted to be non-existent in the sense of the personal knowledge. Therefore the investigations on organizational knowledge are not considered. The learner is always a person – with her/his existing knowledge, which is increasing – a member of an organization. The organization affects the knowledge increase of the person, and this impact is investigated in Sections 6.2 and 7.2.

The nature of knowledge representations could be better understood if children were considered when they form their knowledge representations, i.e. when they

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[1] *This type of knowledge increase is not investigated; it is used to achieve the results of the dissertation.*

make the transition from logic of doing to conceptual logic. (Section 4.2.7) Investigating this transition can get us closer to understanding the nature of knowledge representations. As the knowledge increase is investigated here only after the formation of knowledge representations, the formation process itself is excluded from the examination.

It was shown that the knowledge and the knowledge increase of a (grand)master fundamentally differ from the others'. (Sections 4.1.8 and 4.2.8) In the modelling of knowledge increase, the master is excluded from the investigation. This thesis is focused on the learning of the expert before and after absorbing new knowledge. The reason for this is that the expert level knowledge is the highest knowledge level that can be described and thus modelled.

Both the individual and the organizational value systems are considered already formed before the learning begins. It is acknowledged that the value systems are only the tip of the iceberg; ideas, genes, memes and many others are in the below the surface. The evolution, the formation, the modification, and the functioning of the value system are left out of consideration. The value system is not experienced directly. Everything is compared to the value system, by doing so we make judgments, which are examples of the indirect manifestations of the value system. Only the judgments affecting the knowledge increase are examined here. (Sections 4.1.9, 4.2.9, and 6.2)

There are two further limitations that are going to be introduced in the modelling stage only. These follow from the nature of knowledge but they can be easily described once the preliminary model of knowledge as system is constructed in Section 6.1. Firstly, there is an interaction between the knowledge as (before and after the increase) and the environment (the available knowledge, the individual and the organizational value system, and the attention). The impact of the environment on the knowledge is investigated in this thesis, but the effect of the personal knowledge on the environment is not. (Section 6.1) This would add unmanageable complexity to the investigation and probably would not take much further the understanding of the personal knowledge increase. Secondly, the global structure and the macro-structure of personal knowledge, that is to say the knowledge as a whole, is not investigated,

only the microstructure and some parts of the macro-structure, i.e. the component knowledges to which ones the new knowledge is connected. (Section 6.1)

Now that the boundaries have been revisited, the problem is finally stated in positive for in the next section.

5.3. Stating the Problem

In the first two sections of this chapter the way of getting to the problem formulation was described and then the boundaries, that were introduced in the previous three chapters and two other boundaries that will be formulated in the first section of the next chapter, were revisited, the problem can finally be formulated (actually, as it was explained in the first section of the present chapter, it was formulated near to the end of the investigation). First the problem is described as a list of bullet points and then these are pulled together into a single sentence:

- As the investigation is focused on personal knowledge, one person is examined.

- The person is a member of different organizations, but for this occasion she/he is considered to be a member of a single organization only.

- The knowledge increase by absorbing new knowledge is considered, which is called learning. The new knowledge is considered to be a single particular piece of new knowledge (a single cognitive schema), thus once it is let into the organization the further organizational effects, of e.g. regulating the pace of absorption, can be omitted. (See Section 6.2)

- The examination happens 'here and now', meaning that the temporary state of mind, feelings, emotions, etc. of the individual and similarly the temporary state of the organization is considered; if these are altered the model should be altered too.

- It is examined which factors determine and how if the person learns the new knowledge.

By pulling these together into a single sentence, we get the problem statement:

Which factors determine the increase of personal knowledge that occurs by absorbing a particular new knowledge of an individual, who is a member of an organization, and how these factors work?

The model providing an answer to the above question is called the Model of Learning Ability, and it is the main finding of this research (actually the first main finding is the descriptive version of the model and the second main finding is the knowledge base of it). Here we can already see that the problem could have not been formulated before making certain advance in the investigation, as the problem nodes are actually the factors, which are considered to determine the MLA.

Along the way of problem solving, before actually obtaining a solution, we can say several more things about the findings that are emerging. For this we need a typology of solutions. (Baracskai-Velencei-Dörfler, 2005, p. 91 ff) The solution of a scientific problem is always a new knowledge. We tried to group the new knowledge obtained in scientific problem solving and we have found three categories: new knowledge about a concept/element, new knowledge about functioning (how something works), and new knowledge about the validity of some knowledge. (Table 3)

The main findings of this dissertation assemble a model, which explains the functioning; therefore, they belong to the second category, new knowledge about functioning. The main result is actually a description of how the process of learning works. There is also a result in the mainstream of the research, which is not part of the MLA, which is the main result, i.e. the typologies of knowledge were synthesized; this is a new knowledge about a concept, i.e. about the concept of knowledge.

Table 3: Types of solutions.

Solution of the problem New knowledge...	Question to answer	Form of the solution
About a concept	What?	Description
About functioning	How?	Explanation (model)
About the domain of validity of a piece of knowledge	When/where (not)?	Prognosis

There seems to be a supposed hierachy of these types of solutions; the new knowledge about a concept is rated the lowest, the new knowledge about the validity is rated the highest. It is important to acknowledge that the new knowledge about the validity does not mean only identifying an area where/when something is valid, we also have to identify where/when it is not valid. There are philosophers of science (e.g. Hársing), who take this as the difference between a law and a theory: for a law we know an area where/when it is valid, for a theory we also have to know where/when it is not valid. According to this train of thought, e.g. the Newtonian physics became a theory only when Einstein identified where/when it is not valid.

In this dissertation there is no finding of the third (highest rated) type. Nevertheless, this research may become a seed of a dynamic theory of knowledge, as it will be acknowledged in Conclusions, and for that a third-type result is needed.

Now we finally have the problem formulated explicitly and in a positive form, and the following two chapters will introduced the findings of the research, namely the Model of Learning Willingness, the Model of Learning Capability, and the Model of Attention (one corresponding to each component problem). These are then integrated into a single model, the Model of Learning Ability, which corresponds to the problem stated here. This is the main result of the research.

6. Descriptive Models

> *"The model is, actually, the investigator's structured knowledge of reality; which is easy to transfer and apply for those using, controlling, or adapting to that reality."*
>
> *István Csernicsek[1]*

This chapter presents the four main results of the dissertation. First the system of knowledge and the process of knowledge increase are described adopting a mathematical symbolism. Then three subsequent sections introduce three of the four main results, the Model of Learning Willingness (MLW), the Model of Learning Capability (MLC), and the Model of Attention (MA). Finally these three are integrated into the fourth main result, the Model of Learning Ability (MLA).

Although the present chapter introduces the descriptive models and the new one the simulative ones, it is not how the models were developed. Firstly, the three models (MLW, MLC, MA) were results of three parallel lines of research, which often overlapped and influenced each other. Secondly, the descriptive models and the simulations were also developed in iteration, meaning that when an idea was formed, it was immediately put on test on basis of observations and thought experiments (see Chapter 2 and in particular Sections 2.3 and 2.4); then the ideas were accepted, abandoned, or refined.

So, as it was indicated in Section 2.8, this well-structured presentation of the results has nothing to do with the ill-structured process of achieving them. On a larger scale the research followed the process of scientific problem solving described in Section 2.8 − not surprisingly as that description is based on remembering this process − and on finer scale it was following three interrelated iterative lines (at least three of the original ones remained) which were sometimes divided and then united again.

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[1] *Csernicsek, István (1996) Teorija sistema (System Theory), Stylos, Novi Sad, Serbia & Montenegro, p. 101.*

6.1. Definitions and Description

In this section the mathematical symbols are introduced that are used to describe and examine personal knowledge as system. The elements of the system are the cognitive schemata (as was already described in Section 4.1.2) and the subsystems are called component knowledges. The mathematical symbolism is used as a language only; its use does not imply calculations. The description of knowledge as system is provided through the interpretation of these symbols.

1) The examined object (**Q**) is the personal knowledge (some additional markings for it: existing knowledge $\mathbf{Q_0}$; increased knowledge $\mathbf{Q_1}$; new knowledge $\mathbf{\Delta Q}$)

2) The examination occurs on four planes

- $\boldsymbol{\alpha}$: plane of the mind;

- $\boldsymbol{\beta}$: plane of the personal value system;

- $\boldsymbol{\gamma}$: plane of the organizational value system;

- $\boldsymbol{\delta}$: plane of attention.

3) According to these the projection of personal knowledge on the different planes:

- $\mathbf{Q_\alpha}$: projection of personal knowledge on the plane of the mind;

- $\mathbf{Q_\beta}$: projection of personal knowledge on the plane of the personal value system;

- $\mathbf{Q_\gamma}$: projection of personal knowledge on the plane of the organizational value system;

- $\mathbf{Q_\delta}$: projection of personal knowledge on the plane of attention;

4) Thus the four environments:

- $\boldsymbol{\omega_\alpha}$: $\mathbf{Q_\alpha}$ environment, available knowledge;

- $\boldsymbol{\omega_\beta}$: $\mathbf{Q_\beta}$ environment, personal value system;

- $\boldsymbol{\omega_\gamma}$: $\mathbf{Q_\gamma}$ environment, organizational value system;

- ω_δ: Q_δ environment, attention that the individual can pay;

5) Interactions between the examined object and the environment:

- X_α: $\omega_\alpha \rightarrow Q_\alpha$ the effect of available knowledge on personal knowledge; the source of the new knowledge.

- X_β: $\omega_\beta \rightarrow Q_\beta$ the effect of the personal value system on personal knowledge; it filters the new knowledge;

- X_γ: $\omega_\gamma \rightarrow Q_\gamma$ the effect of the organizational value system on personal knowledge; it filters the new knowledge;

- X_δ: $\omega_\delta \rightarrow Q_\delta$ the effect of attention on personal knowledge; how well can we attend to the new knowledge;

- Y_α: $Q_\alpha \rightarrow \omega_\alpha$ the effect of personal knowledge on available knowledge; if there is something in the increased knowledge that the available knowledge lacks, it can increase the available knowledge – this subject will be avoided in the present study;

- Y_β: $Q_\beta \rightarrow \omega_\beta$ the effect of personal knowledge on the personal value system, since the value system depends on knowledge (among others) it is an existing effect – in this study this important subject will remain unexamined;

- Y_γ: $Q_\gamma \rightarrow \omega_\gamma$ the effect of personal knowledge on the organizational value system, as there is an effect of the knowledge on the personal value system, it directly affects the organizational value system – this will not be analyzed either;

- Y_δ: $Q_\delta \rightarrow \omega_\delta$ the effect of personal knowledge on attention, the relationship of existing and new knowledge affects the attention which could be paid to the new knowledge;

6) Component-knowledges, elements and relations:

- Q^i i = (1, …, m): the component-knowledge, according to this Q_α^i, Q_β^i, Q_γ^i, Q_δ^i are the projections of the component-knowledge on the

examination planes – vectorially: $\underline{Q}$ and its projections $\underline{Q}_\alpha$, $\underline{Q}_\beta$, $\underline{Q}_\gamma$, $\underline{Q}_\delta$ **m**-dimension vectors;

- e^j **j = (1, …, n)**: the elements are the cognitive schemata, according to this e_α^j, e_β^j, e_γ^j, e_δ^j are the projections of schemata on the examination planes – vectorially: $\underline{e}$ and its projections $\underline{e}_\alpha$, $\underline{e}_\beta$, $\underline{e}_\gamma$, $\underline{e}_\delta$ **n**-dimension vectors;

- $R_Q^{k,l}$ **k,l = (1, …, m)**: the relations between the component-knowledges, according to this $R_{Q\alpha}^{k,l}$, $R_{Q\beta}^{k,l}$, $R_{Q\gamma}^{k,l}$, $R_{Q\delta}^{k,l}$ are the projections of the relations on the examination planes – vectorially: $\underline{\underline{R}}_Q$ and its projections $\underline{\underline{R}}_{Q\alpha}$, $\underline{\underline{R}}_{Q\beta}$, $\underline{\underline{R}}_{Q\gamma}$, $\underline{\underline{R}}_{Q\delta}$ **m×m**-dimension tensors;

- $R_e^{k,l}$ **k,l = (1, …, n)**: the relations between the cognitive schemata, according to this $R_{e\alpha}^{k,l}$, $R_{e\beta}^{k,l}$, $R_{e\gamma}^{k,l}$, $R_{e\delta}^{k,l}$ are the projections of the relations on the examination planes – vectorially: $\underline{\underline{R}}_e$ and its projections $\underline{\underline{R}}_{e\alpha}$, $\underline{\underline{R}}_{e\beta}$, $\underline{\underline{R}}_{e\gamma}$, $\underline{\underline{R}}_{e\delta}$ **n×n**-dimension tensors;

7) Structures:

- $S_e^{(i)} = (\underline{e}^{(i)}, \underline{\underline{R}}_e^{(i)})$ **i = (1, …, m)**: the microstructure of an **i**th component-knowledge ($\underline{e}^{(i)}$ is the vector of the cognitive schemata of the **i**th component-knowledge, $\underline{\underline{R}}_e^{(i)}$ is the tensor of the relations between the schemata of the **i**th component-knowledge) – vectorially: $\underline{S}_e$ **m**-dimension vector, the projections are composed similarly to the above;

- $S_Q = (\underline{Q}, \underline{\underline{R}}_Q)$: the structure of the whole knowledge, the macrostructure, the projections are composed similarly to the above – the examination of the whole knowledge is impossible (see explanation below Figure 28), therefore the macrostructure is not examined;

- $S = (\underline{S}_Q, \underline{S}_e, \underline{Q}, \omega, X, Y)$: the global structure, which describes the whole knowledge, the environment and the interactions between them; similar to the macrostructure, it cannot be examined, and thus will be omitted.

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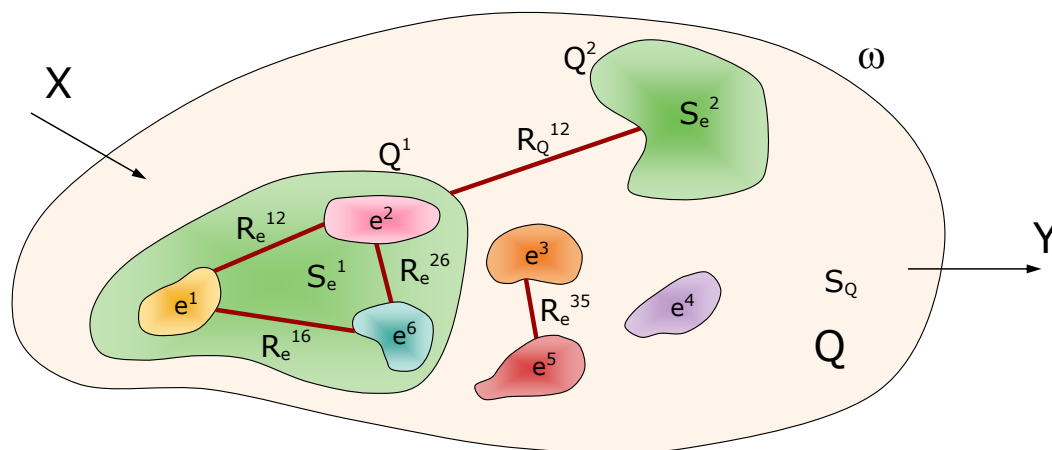
Figure 28: The microstructure, the macrostructure and the global structure.

The symbols that have been introduced correspond to a full description of a system; however, considering some special features of personal knowledge and the present examination some simplifications can be made. The subsystems of knowledge, viz. component knowledges that are not ephemeral, as described here, correspond to meta-schemata explained in various sections of Chapter 4. It was also said that schemata can only be examined while they are in STM. Everyone knows more than 7 ± 2 complex things – not necessarily on master-level but unquestionably at meta-schema-level[1] –, e.g. we can talk, write, ride a bicycle, make coffee, etc. If we have more meta-schemata then we can retrieve into our STM at once, the macrostructure and global structure of knowledge cannot be examined. Thus henceforth the macrostructure (S_Q) and the global structure (S) are abandoned and the microstructure (S_e) is replaced by meta-schema (M). To be more precise, in structures of component knowledges (in meta-schemata) there may be meta-schemata too, along with the elementary schemata due to the hierarchical structure; thus we also have some of the relations between the component-knowledge (Q) described in meta-schemata. It means that, although we do not know the whole macrostructure (S_Q), some parts of it we do. Therefore it is not essential to distinguish the relations between component-knowledges (R_Q) from the relations between schemata (R_e); so from now on only a single tensor of relationships will be used in describing both the relations between

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[1] *It is estimated that most of our common sense is around expert level, as, for instance speaking in our mother tongue, or handling everyday situations. ([Mérő, 1990](), p. 122)*

schemata and those between meta-schemata (component-knowledges). For distinction a marking without index (**R**) will be used.

Now we have the symbolic language ready to analyze knowledge as system and to describe the forthcoming models.

6.2. Learning Willingness[1]

From the interaction of personal knowledge and environment on the plane of value systems only the input, the impact of the environment on personal knowledge ($\mathbf{X}$: $\omega \rightarrow \mathbf{Q}$) is analyzed. Three environments are involved, the available knowledge (ω_α) as the source of new knowledge and the two value systems (ω_β, ω_γ).

It may well be that we can assume a kind of a static balance before the knowledge increase, but we must be aware that the increased personal knowledge has an impact on the environment ($\mathbf{Y}$: $\mathbf{Q_1} \rightarrow \omega$). If something evolves in increased personal knowledge of someone that has previously not been part of the available knowledge, the personal knowledge may add something to the available knowledge ($\mathbf{Y}$: $\mathbf{Q_1} \rightarrow \omega_\alpha$). Since the value system depends (amongst others) on knowledge, it is obvious that the personal knowledge affects the increased personal value system ($\mathbf{Y}$: $\mathbf{Q_1} \rightarrow \omega_\beta$). The effect on the organization's value system ($\mathbf{Y}$: $\mathbf{Q_1} \rightarrow \omega_\gamma$) is indirect. The value system of a person with increased knowledge changes; with her/his samples she/he affects the organizational value system.[2] These effects of the increased personal knowledge may be interesting but in the present dissertation they are not investigated.

The original idea was to frame the three environments into each other, so only the new knowledge coming from the available knowledge that is let through the organizational filter would reach the individual, who could then judge it using her/his personal value system. This idea was, however, contradicted by experience that sometimes individuals learn something that would never get through the organizational

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[1] *The result presented in this section is published as a conference paper. ([Dörfler, 2003](#))*

[2] *The second stage of this effect is similar to the situation when a new person becomes member of the organization.*

value system. The idea was refined in the next step, assuming a selective filter for the organizational value system, which lets through everything but some new knowledge with great difficulty, while the other would be even pushed towards the individual. This model seemed to be accurate but extremely difficult to handle (or to explain).

Finally the following model was adopted to start with (Figure 29): The new knowledge reaches the organizational value system, which makes a judgment upon it. The new knowledge also reaches the personal value system, and it is accompanied by the organizational judgment. The next step is a direct interaction between the personal and organizational value system, and finally the person decides to learn this new knowledge or not.
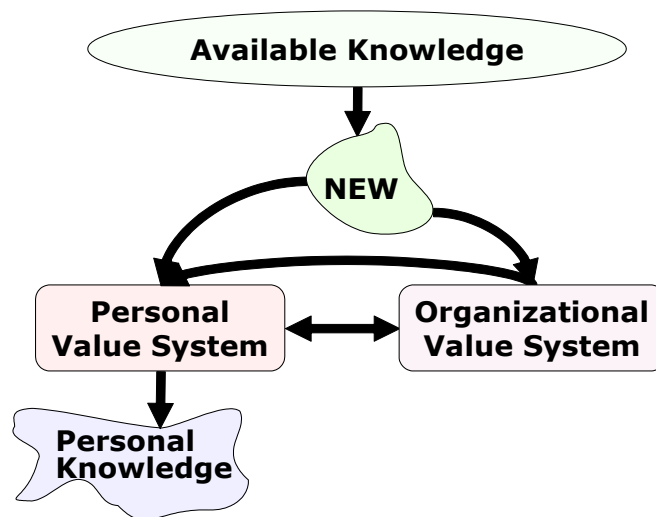
Figure 29: Two judgments about the new knowledge.

Before turning to the explanation of the interaction between the two value systems; there is a question that can be reasonably asked: Do we always consciously take the decision to learn something or not? The answer is borrowed from Anderson (2000, p. 195):

"... a factor that does not affect memory despite people's intuitions to the contrary: It does not seem to matter whether people intend to learn the material; rather, what is important is how they process the material."

This means that judgment, i.e. the evaluation by the value system is what matters, conscious or not. If we like something (high value) then we can process it well, if we dislike something (low value) the processing will be poor.

The suggested values for the judgements of the personal value system were promising, neutral, and ominous; for the judgements of organizational value system they were useful, indifferent, and harmful. For the easier demonstration of the interactions of the two value systems the middle values are removed; this does not affect the logic of the argument.

If a particular new knowledge is useful (for the organization) and promising (to the individual), it is easy to conclude, the individual will accept it. It is also easy to see that if it is harmful and ominous then the individual does not accept it. These two states of the model are stable. But what happens in other cases? The judgment comes from the interaction of personal and organizational value systems; they affect each other – by influence. How can a new knowledge go from one box to another one? It is done by this influencing as well. There can be two directions of the influence: the positive influence (directions of blue arrows in Table 4) and the negative influence (directions of red arrows in Table 4).

Table 4: Influence between the two value systems.
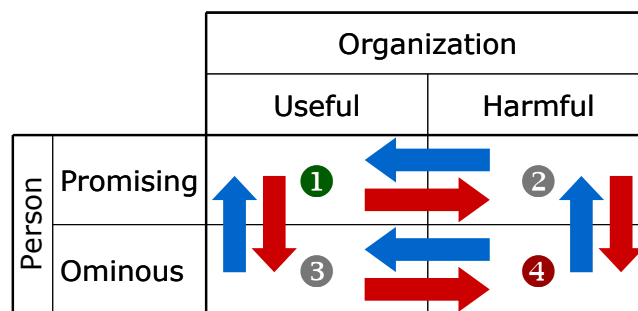
If new knowledge is promising and harmful (state ❷), or ominous and useful (state ❸), the person and the organization are influencing each other to change the judgment. The resistance acts opposite to the influence. The symbols used for description are functions[1] this time:

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[1] *They are actually symbols only following the mathematical formalism of functions.*

- Both, the person and the organization have their first judgment: $V_{person}(\Delta Q)$ and $V_{org.}(\Delta Q)$

- The organization uses a normative influence on the person, namely it orders: $I_{org.}^{n}(\Delta Q)$.

- The person influences the organization by setting examples, namely she/he tries to show that the judgment of the new knowledge should be changed: $I_{person}^{s}(\Delta Q)$.

- The person resists reconsidering her/his judgment: $R_{person}(\Delta Q)$.

- The organization resists the reconsideration of its judgment: $R_{org.}(\Delta Q)$.

There are two unstable states (❷ and ❸ in Table 4). How can they be re-boxed?

In positive influence (Table 4, blue arrows) the person and the organization try to make each other change the judgment to higher value. With the markings above:

$❷ \rightarrow ❶$: $\quad g\left(I_{person}^{s}(\Delta Q), R_{org.}(\Delta Q)\right)$

> The person influences the organization by setting examples, showing that the promising new knowledge is not harmful to the organization but useful.

$❸ \rightarrow ❶$: $\quad g\left(I_{org.}^{n}(\Delta Q), R_{person}(\Delta Q)\right)$

> The organization orders the person to acquire the new knowledge.

In negative influence (Table 4, red arrows) the person and the organization try to achieve the change of each others' judgment to a worse value. With the markings above:

$❸ \rightarrow ❹$: $\quad g\left(I_{person}^{s}(\Delta Q), R_{org.}(\Delta Q)\right)$

> The person influences the organization by setting examples, show-

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ing that the ominous new knowledge is not useful to the organization but harmful.

❷→❹: $\quad g\left(I_{org.}^{n}(\Delta Q), R_{person}(\Delta Q)\right)$

The organization orders the person to abandon the new knowledge.

A further analysis shows that it is possible to displace new knowledge, not only from an unstable situation, but also from the stable ones too. For this we need new players, since neither the person nor the organization wants to reconsider the new knowledge (these were not necessary in the previous part of analysis but if they are present they can strengthen the described effects, or they may also influence the primary judgement):

- The recommendatory may influence the person to reconsider the new knowledge, by setting examples – the recommendatory can be the mentor: $I_{mentor}^{s}(\Delta Q)$.

- The organization may be influenced by its environment to reconsider a new knowledge. It is possible by setting examples, e.g. if a rival starts to use a new knowledge; or normatively e.g. if a political authority commands: $I_{env.}^{s/n}(\Delta Q)$.

With help of the external characters, new knowledge can be tipped from a stable ominous-harmful position, but both the person and the organization resist:

❹→❷: $\quad g\left(I_{mentor}^{s}(\Delta Q), R_{org.}(\Delta Q), R_{person}(\Delta Q)\right)$

By setting examples, the mentor influences the person to re-value the ominous knowledge to promising; the person moderately doubts and the organization is troubled because somebody is engaged with the harmful new knowledge. ❷→❶ or ❷→❹ may end the instability this situation.

❹→❸: $g\big(I_{env.}^{s/n}(\Delta Q), R_{org.}(\Delta Q)\big)$

> The environment influences the organization by using sample and/or norm to modify the judgment of the harmful knowledge, organization resists (the person resists too but it is negligible). After this, ❸→❶ or ❸→❹ may follow.

The external characters may initiate the re-boxing of the useful-promising new knowledge as well, and there will be resisting from both the person and the organization likewise in previous situation:

❶→❸: $g\big(I_{mentor}^{s}(\Delta Q), R_{org.}(\Delta Q), R_{person}(\Delta Q)\big)$

> By setting examples, the mentor tries to convince the person that the new knowledge is not promising, the person moderately doubts and the organization is uneasy that the useful new knowledge may be ignored. This re-boxing may be followed by ❸→❶ or ❸→❹.

❶→❷: $g\big(I_{env.}^{s/n}(\Delta Q), R_{org.}(\Delta Q)\big)$

> The environment influences the organization by using sample and/or norm to abolish the useful new knowledge, organization resists (the resist of the person is negligible as well as previously). There are, again, two ways from this instability, ❷→❶ or ❷→❹.

If all the considered influences are put together in a function, we can define the *influencing function*. Its default variable is the new knowledge. Considering all of the previously described effects and substituting the unknown *«g»* function with *«i»* for influence:

$$i(\Delta Q) = i\big(I_{person}^{s}(\Delta Q), I_{org.}^{n}(\Delta Q), R_{person}(\Delta Q), R_{org.}(\Delta Q), I_{mentor}^{s}(\Delta Q), I_{env.}^{s/n}(\Delta Q)\big) \qquad [1]$$

So, how does the person, who is a member of an organization, decide to learn the new knowledge or not? Her/his willingness depends on judgments of his personal

value system (V_{person}) and of the organizational value system ($V_{org.}$), as well as their influencing function.

$$w(\Delta Q) = w\big(V_{person}(\Delta Q), V_{org.}(\Delta Q), i(\Delta Q)\big) \qquad [2]$$

The function defined this way is the ***learning willingness*** – it is a mathematical form of the model. It is impossible to calculate it, as there is no measuring behind but subjective judgements. If we do not want to enforce quantification of human opinion, which is not quantified by nature, we can transcribe the relations with logical rules – as it is done in the corresponding Section 7.2. To do this, values of learning willingness are also to be defined; again arbitrarily-chosen three values: *«require»*, *«accept»*, and *«reluctant»*. Another way of illustration would be if we drew a picture. Thus, an illustrative graphical example is introduced to show the non-linearity of the function. The example is representational of the nature of the function rather than being a model determined from specific data.

If we presume that the effect of the mentor and of the environment are completed (i.e. the stable states are not changed any further), the influencing function can be expressed with the personal and the organizational value systems, thus the function of learning willingness can be also expressed using only these two variables. With this presumption we can draw a picture, which shows the behaviour of the function. (Figure 30) There is no mathematical relation; it is just a picture that helps the orientation:

- an axis is assigned to personal value system: the range of $V_{person}(\Delta Q)$ becomes one dimension of the domain of $w(\Delta Q)$, which is represented by the *[-1,1]* closed interval, where promising is *1*, neutral is *0*, and ominous is *-1*;

- another axis is assigned to the organizational value system $V_{org.}(\Delta Q)$; the range of it becomes the other dimension of the domain of $w(\Delta Q)$, also represented by the *[-1,1]* closed interval, where useful is *1*, indifferent is *0*, and harmful is *-1*;

- the range of function *w(ΔQ)* is also the *[-1,1]* closed interval, where require is *1*, accept is *0*, and reluctant is *-1*;

- the points of the function *w(ΔQ)* are plotted using logical rules like: «if the new knowledge is promising and useful, then the person will require it» → *(1,1,1)*;

- between the points generated by logical rules interpolation[1] is used.

Two individuals, the ones with the most differing value systems, from the observation (from the Apprenticeship School, cf. Section 2.4) were chosen to construct this example. Figure 30 shows the learning willingness of the two individuals, dedicating a surface to each of them. The position of new knowledge in the personal value system is indicated on the *x*-axis; the position of new knowledge in the organizational value system on the *y*-axis. On *z*-axis the learning willingness is shown.
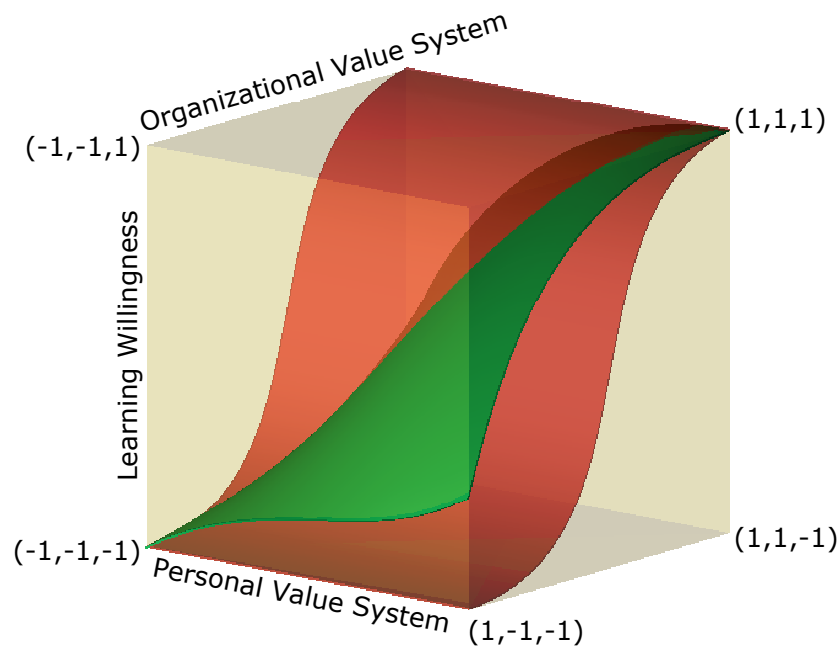
Figure 30: 3D picture of the *Learning Willingness*.

Person *A* (green surface) is less sensitive to the judgments of the organizational value system than person *B* (red surface). However, *A* is much more sensitive to the judgments of his own personal value system than person *B*. If a new knowledge is

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[1] *In this particular case it was done using spline-interpolation.*

promising to **B**, but harmful to organization, his learning willingness gets the lowest *«reluctant»* value. **A** *«accepts»* the new knowledge in the same situation. But in contrast, if new knowledge is *«ominous»*, **A** is *«reluctant»* even if it is *«useful»* for organization. In the same situation **B** not only *«accepts»* but *«requires»* it. Naturally, new knowledge in *«promising»-«useful»* position both will *«require»* and the for *«ominous»-«harmful»* new knowledge both are *«reluctant»*-s. Because of these corner positions two surfaces intersect. It is easy to read who has higher learning willingness towards a particular new knowledge, on the basis of the picture – whose surface is higher.

There is another graphical solution, perhaps for some even easier to handle: just take the view from above on the 3D picture and plot in 2D what you see (Figure 31). From this viewpoint the judgment of organizational value system marks a line, which is parallel to x-axis (personal values system). Personal value systems judgments will plot points on this line.
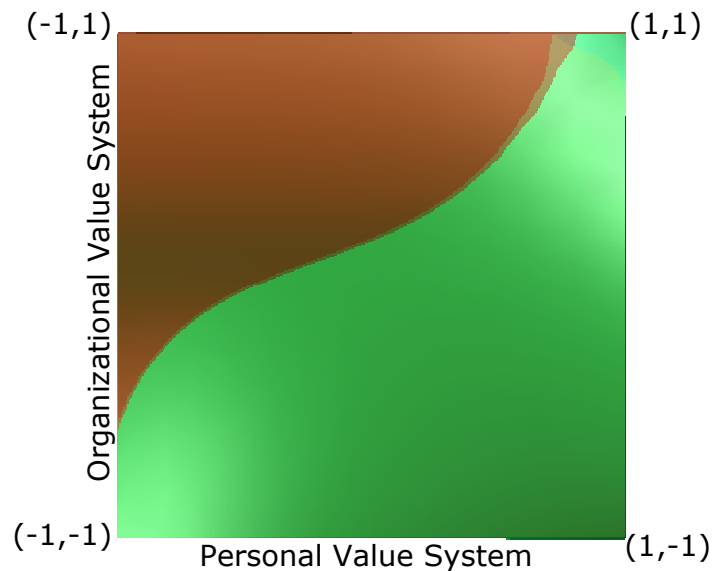
Figure 31: The *Learning Willingness* model from above.

It is simple if both points are in the same area (green or red surface); it means that on that part the surface that is seen covers the other one, so the learning willingness of one person is higher on that area (the green area indicates person **A** while the red area person **B**). However, it may easily happen that new knowledge is *«promising»*

to one, and *«ominous»* to the other person, therefore the points may not fall into the same area – then the 2D picture is useless.

Either one prefers the graphical presentations or the mathematical description. One may make qualitative inferences about the learning willingness of a person based on the two value judgments about the new knowledge (i.e. the person's individual judgment and the judgment of the organization) and on the mutual influence of the two value systems. The learning willingness describes whether the person is willing to acquire the new knowledge; together with the learning capability and the attention it will be used to model the learning ability of the person.

6.3. Learning Capability[1]

The model of learning capability aims at plane of mind only. The new knowledge reaches the existing knowledge and joins it, which results in increased knowledge. (X: $\omega_\alpha \rightarrow Q_0$) As in the previous model, the impact of increased knowledge on available knowledge (Y: $Q_1 \rightarrow \omega_\alpha$) is not investigated. The goal of this model is to throw light on how the features of existing personal knowledge of the individual in relation to the features of the new knowledge affect the knowledge increase. The description is similar to the previous model meaning that mathematical symbolism is used; in addition the previously introduced markings, new ones are added for the present discussion.

We can describe problem solving as covering the problem domain with the required knowledge. Some parts of it are covered with the existing knowledge (Q_0). The uncovered area can be covered with the new knowledge (ΔQ). When the new knowledge is absorbed we get the increased knowledge (Q_1). The problem domain does not have sharp boundaries, neither does the knowledge. If we start from the problem domain, we cannot know if our increased knowledge will cover it. However, for each piece of knowledge an applicable problem domain (or a component-problem) can be found. Therefore the examination can be conducted backwards, con-

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[1] *The result presented in this section is published as a conference paper. ([Dörfler, 2004a](#))*

sidering the problem domain (P_1), which is covered with the increased knowledge (Q_1) at the end. (Figure 32)

If the knowledge was simply additive then the increased knowledge would simply happen as:

$$Q_1 = Q_0 + \Delta Q \qquad [3]$$

But, as we have seen in Chapter 4, knowledge is not simply additive. Our schemata exist only through their relations. We cannot have a schema, which is not connected to other ones. This also means that we can only learn things that can be connected to our existing knowledge. If a schema is connected to the other schemata, then they will affect each other.
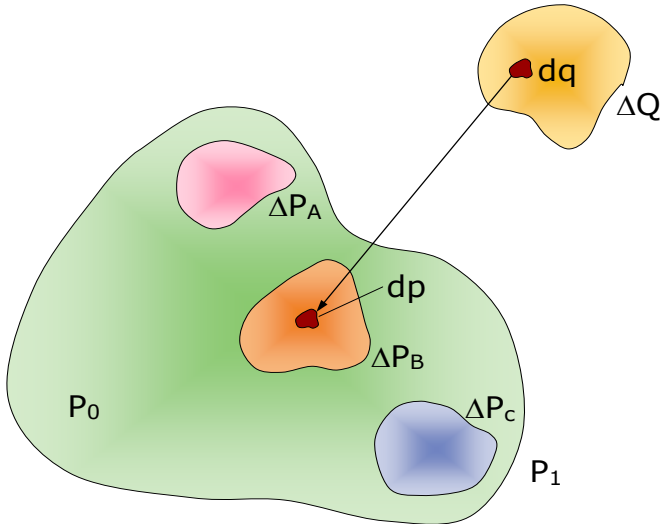
Figure 32: Absorbing new knowledge.

Let Q_0 be the (existing) knowledge that can cover the P_0 problem domain, ΔQ new knowledge covers the ΔP problem domain, and Q_1 increased knowledge covers the P_1 problem domain. Then:

$$P_1 = P_0 \oplus \Delta P, \text{ where } \Delta P = \Delta P_A \oplus \Delta P_B \oplus \Delta P_C \qquad [4]$$

Instead of addition, distinctive marking was applied as the additive problem domain makes no more sense than the additive knowledge. The $\oplus$ marking means 'the A, the B and the C component-problems together'.

Using these markings, the new knowledge can be described as:

$$\Delta Q = \int_{\Delta P} g(q)dq \qquad [5]$$

Here, **dq** is an infinitesimal unit of knowledge, and **g(q)** is, once again, an unknown function. Since schemata are considered to have limited sizes, the integration could be substituted with a sum. However, this mathematical description is easier to handle and knowledge is easier to interpret if it is connected to a problem domain. As neither the previously mentioned nor the forthcoming integrals are going to be calculated, there is no benefit in summative description. The existing knowledge can be presented similarly to the previous:

$$Q_0 = \int_{P_0} g(q)dq \text{ ; if it is not a scientist, then } \lim_{P \to P_0} g(q) = 1 \qquad [6]$$

The formula means that knowledge is not changing if we do not learn something new. This observation serves as a starting point to draw conclusions about the **g(q)** function. The scientist is used as a metaphor for the individual who increases her/his knowledge not only by absorbing new knowledge but also by rearranging her/his existing knowledge. Therefore limit of **g(q)** on **P₀** will not equal **1**. It does not mean that this type of the knowledge increase takes place on **P₀** because the covered domain will also change. The existing knowledge – not for the scientist only – also changes during the knowledge increase:

$$Q_0^* = \int_{P_0} g(q)dq \neq Q_0 \qquad [7]$$

To describe the increased knowledge, the only thing to be done within the present symbolism is to consider the integrals at the **P₁** problem domain:

$$Q_1 = \int_{P_1} g(q)dq \neq Q_0 + \Delta Q \qquad [8]$$

The function **g(q)** will not be determined in the form of an equation. However, important conclusions could be made about its character. It was stated earlier (Sec-

tion 6.1) that the elements of knowledge as system are the cognitive schemata ($\underline{e}$), with relations among them ($\underline{\underline{R}}$), and some of these relations are organized in a structure, described by the meta-schemata ($\boldsymbol{M}$). Thus the following working hypothesis is used:

$$g(q) = g\left(\underline{e}, \underline{\underline{R}}, M\right) \qquad [9]$$

The knowledge increase is a process, which happens in time. We may observe that different people learn the same new knowledge at different speed; the same person acquires different pieces of new knowledge at different speed. Therefore it is reasonable to consider the partial differentials of the mentioned variables by time as well. For these the following markings will be used:

$$\dot{\underline{e}} = \frac{\partial \underline{e}}{\partial t}, \ \dot{\underline{\underline{R}}} = \frac{\partial \underline{\underline{R}}}{\partial t}, \text{ and } \dot{M} = \frac{\partial M}{\partial t}, \text{ where } \boldsymbol{t} \text{ is time} \qquad [10]$$

Now we shall examine the six variables, to determine, which are the needed ones for the function $\boldsymbol{g(q)}$, i.e. which ones are not zeros:

$\underline{e}$: Are there any schemata to which the new knowledge can be connected? − As we can absorb only the schemata, which can be connected to existing ones. So, the schemata are to be considered in the function.

$\dot{\underline{e}}$: In the present dissertation the schemata are considered to be permanent. We either have a schema for something or not; a changed schema is a new schema. So the speed of change of schemata has no significance; thus this variable is left out of consideration.

$\underline{\underline{R}}$: The relations among the schemata are changing fast. The relations that are more stable are described by the structures, i.e. by meta-schemata. Therefore the existing relations between the existing schemata are not considered for a stand-alone variable.

$\dot{\underline{\underline{R}}}$: The speed of change of relations is of high importance. If we have schemata to which the new knowledge can be connected, it is crucial

how fast the relations evolve. Thus the differentials of the relations by time are taken into account.

M : It is important to know if there is a structure into which the new knowledge fits, and, as it was said previously, the more stable relations are described by meta-schemata and they are not yet considered. Consequently the meta-schemata are accepted for a variable.

$\dot{M}$: The creation and the modifications of meta-schemata happen with enlightenment, that is to say, in zero time. Suddenly the new image is formed. Since the enlightenment is not investigated in this thesis, the speed of change of meta-schemata is considered.

Applying these consideration on function $f(q)$:

$$g(q) = g\left(\underline{e}, \underline{\dot{e}}, \underline{\underline{R}}, \underline{\underline{\dot{R}}}, M, \dot{M}\right) \approx g\left(\underline{e}, \underline{\underline{\dot{R}}}, M\right)$$ [11]

What is the meaning of the considered variables?

- Does the person have schemata to which' the new knowledge can be connected? – Is she/he capable of learning it at all?

- At what speed is the person able to build in the new schema among the existing ones? – How fast will she/he learn it?

- What kind of structure will receive the new schema? – How deep will the learning be?

The function, answering these questions, will be called the ***learning capability***, and it will be described by the following marking:

$$c(q) \approx c\left(\underline{e}, \underline{\underline{\dot{R}}}, M\right)$$ [12]

For the particular new knowledge, the expression of the learning capability will be:

$$c(\Delta Q) \approx c\left(\underline{e}(\Delta Q), \underline{\underline{\dot{R}}}(\Delta Q), M(\Delta Q)\right)$$ [13]

Now a personal story of coming to these variables is going to be told; it can be considered as a case study for Section 4.2.8.

> *I was casting about for the factors for the MLC, somewhere around STM and LTM. Naturally I got stuck (for a trivial reason, I would say with hindsight), as STM has nothing to do with the learning capability, unless we are to find out who is nearer to 5 and who is nearer to 9 of 7±2 schemata in STM. My mentor Zoltán Baracskai glanced at my drawing, spent a few minutes above it, then said: "Let it be the LTM, the speed and the meta-schemata!" I was not sure why it would be exactly like that, though I was sure that asking him about the 'why' would be meaningless at that moment.*
>
> *The investigation was going along several lines at the same time, and for one of the other lines I was to find out what happened if the schemata, the relations and the structures were derived by time. I was finishing that next day, and in the evening I could not suppress the laughing when I was asking my mentor if he would know why these were the particular variables to be considered. I showed him the system theory deduction.*

The story is telling two different ways of getting to the same result; the way of the (grand)master and the way of the advanced-level disciple. Either of the two would do, but in this case, both were used. The (grand)master's way is faster and the advanced-level-way is easier to explain/justify.

To draw a picture about the function of learning capability, which has three factors we would need a four-dimensional plot, thus three pieces of two dimensional ones will be used instead, each showing the learning capability changing as function of only one variable while the other two are fixed (constant). Of course, as we have lost something in the 2D picture in the previous model we are certainly losing something here as well. The simulative model in Section 7.3 will cover these missing parts in form of logical rules. It is emphasized here too that these are not plots of the functions but only conceptions, in other word pictures.

No. of Schemata: The learning capability by the number of cognitive schemata in the discipline is similar to an exponential function (Figure 33). It comes from the observation that a talented disciple needs about two years to increase the number of schemata by ten times (as described in Section 4.2.8). Therefore the picture applies only to the person, who is talented enough to absorb the new knowledge. The picture is also consistent with the exponential law from GST (Bertalanffy, 1969, pp. 61-62), i.e. that the growth is proportional with the number of elements of the system.
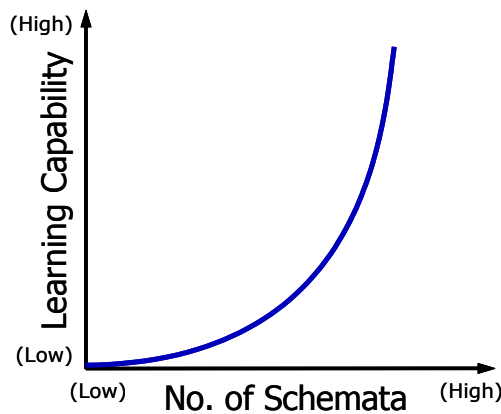
Figure 33: *Learning Capability* by the number of schemata.

Speed: The faster one changes the relations among one's schemata, the faster one will absorb the new knowledge. Therefore the first part of the learning willingness as function of speed is linear. However, above a certain speed the increase of speed does not bring any further increase to absorption of new knowledge, so the curve will flatten out with a horizontal asymptote. (Figure 34)
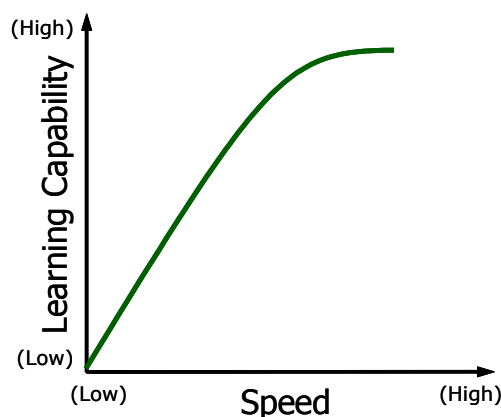
Figure 34: *Learning Capability* by the speed of changing relations.

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Meta-schemata: Meta-schemata, which contradict the discipline where the new knowledge belongs, block the absorption of the new knowledge. The more of these meta-schemata, the stronger the blockade will be. By decreasing the number of contradictory meta-schemata and increasing the number of consistent meta-schemata, the learning capability suddenly increases. The worst is to have many contradictory meta-schemata, though the best is not to have many consistent ones, only a few of them. This can be explained by two factors:

First, according to the hierarchical nature of the meta-schemata, if one has many meta-schemata that the new knowledge can be connected to, then these are probably low-level meta-schemata; i.e. as high-level meta-schemata cover large domains, there cannot be many of them in the area of the new knowledge.

Second, someone having a number of meta-schemata to connect the new knowledge to is likely to feel anxiety. (See next Section) Similarly to the previous picture, the function finally flattens with a horizontal asymptote. (Figure 35) This picture is consistent with the logistic law from GST, i.e. about the growth of population in a system with limited resources, while the previous statement, that the fewer number of consistent meta-schemata is better than many of them, can also be understood from a system indicating competition. (Bertalanffy, 1969, pp. 62-66)
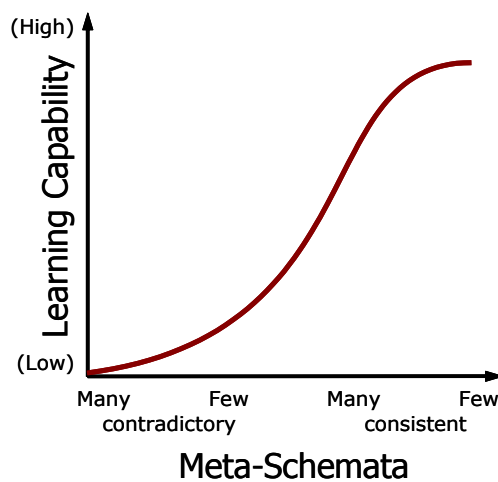
Figure 35: *Learning Capability* by the meta-schemata.

6.4. Attention[1]

The model of attention is introduced in this section based on significant preparatory work done on models of attention and motivation in Sections 3.5 and 3.6. The starting point is that the person is already willing to pay attention to the new knowledge; now the question is if she/he is able to do it. Here are only two groups of factors examined: the cognitive factors refer to the relationship of the new knowledge and existing knowledge (unlike the MLC which was exclusively about the existing knowledge in the field assigned by the new knowledge, the difference is huge and it will be highlighted), and the motivational factors are about the motivational conditions of the person at the time of knowledge increase.

This also means that many possible factors are left out of consideration in the present model, e.g. several impacts of the environment are possible and not examined like noise, temperature, etc. They are omitted as their impact can usually be ignored, i.e. when they are weak and attention is otherwise high; on other occasions, when they are very strong they interrupt the process of knowledge increase completely and the effect is obvious and probably the same for any individual. The environmental impacts are also so diverse that it is impossible to model them.

There are also factors of the group participating in the process of knowledge increase and other impacts of the social environment. These are also ignored in the present investigation but they are acknowledged, their place is assigned in the model, i.e. they would be described within the social level of motivation (cf. Section 3.6), which is here described by love only. These other social factors are not included as they require complete research dedicated to them; this is one of the identified future research directions.

The cognitive factor of attention is modelled starting from Csíkszentmihályi's (2002) Flow conception, but, as it was said earlier, first it needs to be converted into a more convenient form. The first step of this is done by Baracskai and Velencei (2004b, pp. 125-129); they applied the approach of cognitive psychology to the Flow

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[1] *The result presented in this section is published as a conference paper. (Dörfler, 2004b)*

conception, and the result can be seen on Figure 36. Both the knowledge and the expectations are expressed by the number and complexity of cognitive schemata.
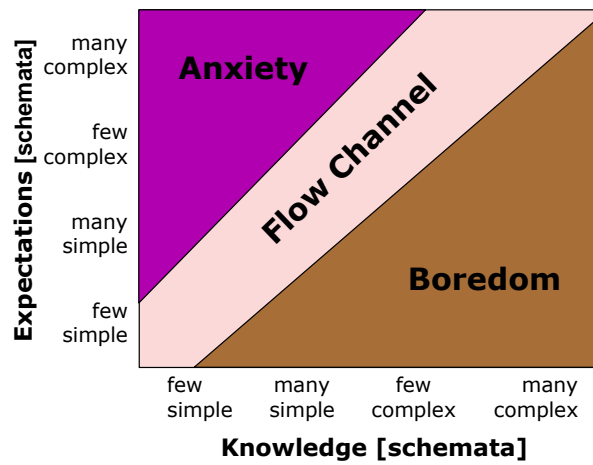
Figure 36: The cognitive dimension of Flow experience.

This adopted version of the Flow conception relates to the work of the knowledge worker; this is the reason that we can have expectation for and knowledge of many complex schemata. As it was said in the previous section, in a process of knowledge increase, where the new knowledge is considered to be a single schema, it is impossible that it can be attached to many schemata of high complexity. It also should be noted that in the previous figure schemata and meta-schemata are both presented, i.e. high complexity schemata are necessarily meta-schemata. For the present model we should redraw the figure in three different planes, i.e. for schemata, for speed of relation changes, and for meta-schemata; similarly to the MLC. It will be done the same way as previously, i.e. by fixing two variables and changing only one.[1]

No. of Schemata: The learning capability was higher if there were more schemata the new knowledge could be connected to. In case of attention (Figure 37), the situation is very different. If we have no appropriate schemata, we cannot pay any attention to the new knowledge; we can even feel anxiety as we do not understand anything. The situation remains the same as the first appropriate schemata appear, until we realize that we should be able to understand what is said (the learning capability

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[1] *And again, as in previous cases, the figures are pictures only, they show tendencies to facilitate the understanding – and they will not be calculated.*

is higher than zero), but as there are very few of these schemata, we can connect the new knowledge much faster than it is delivered, and thus we are bored.
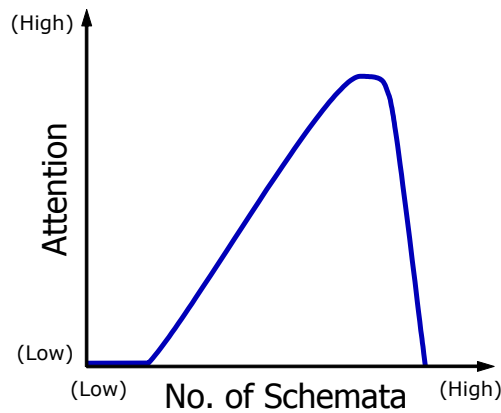
Figure 37: *Attention* by number of schemata.

Gradually, as we have more and more appropriate schemata, the attention increases, and reaches its maximal value. After that, the number of appropriate schemata further increases, and, as we have so many appropriate schemata, probably we also have the one that is being delivered. In this case we experience boredom of listening what we already know, and we lose attention.

If there are lots of appropriate schemata but the new knowledge is not covered, it is delivered at certain speed and there are structures into which we should build in the new knowledge, we are lost – we experience anxiety. If we observe a learner at the end of advanced level (almost an expert), who can determine her/his own speed of acquiring a new knowledge, we can witness that she/he will usually need more time than a beginner.

Speed: The faster we can change the interrelations between our schemata, the better our learning capability is until it reaches the limit where it does not cause further increase. But in case of attention (Figure 38), our variable is not actually the speed at which we can change these interrelationships but the ratio of the speed at which the new knowledge is delivered and the speed at which we can change the interrelations of our schemata. (In the case of schemata the difference was the same but, as a single-schema new knowledge is considered, it was not really manifest.)

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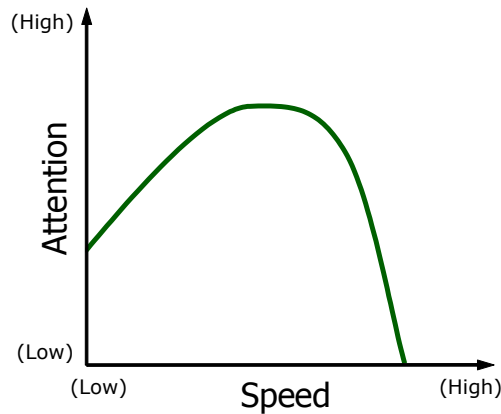
Figure 38: *Attention* by the speed of changing relations.

If the new knowledge is delivered at a significantly lower pace than the rate at which we could change the interrelations of our schemata, we will be bored; but, if the number of schemata and meta-schemata is appropriate we will probably still pay some attention (if not all the time, then at least we do some 'sampling' of what is going on).

As the delivery pace of the new knowledge approaches our convenient speed of changing the interrelations, we are gripped with the new knowledge, we reach the best attention level we are capable of. If the speed further increases, we start to lose the track, more and more often, it is tiring to attend; finally our attention breaks down, we experience anxiety.

Meat-schemata: From understanding the relation of attention and meta-schemata (Figure 39) we will also get the missing piece of understanding about the learning capability by meta-schemata from the previous model. If we have numerous meta-schemata that contradict the new knowledge, we will pay no attention whatsoever; we actually think that the new knowledge is stupidity. We are bored to death. But to have this opinion we have to pay *some* attention.
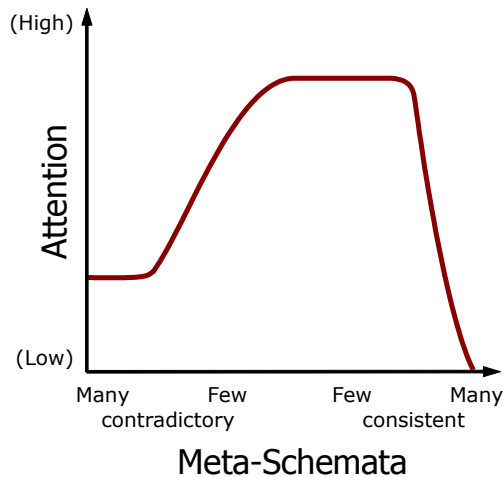
Figure 39: *Attention* by meta-schemata.

As the number of contradictory meta-schemata decreases and the number of consistent meta-schemata increases, we find it easier to attend and gradually we reach the Flow-state. Everything makes sense.

But the number of consistent meta-schemata increases further. We should incorporate the new knowledge into more and more structures. We must not forget that these cannot be high-level meta-schemata, as there could not possibly be many of them exactly in the area of the new knowledge. The pace at which the new knowledge is delivered remains the same, so we should build the new knowledge into our numerous low-level meta-schemata at a pace which is higher than which would allow us to accomplish all these meta-schemata enhancements. We cannot pay attention anymore. We are anxious.

This discussion accounts for the order of values for the meta-schemata in the MLC. The same reconstruction could be done here as well, and not only for the meta-schemata but for all the three factors. If we did do that, we would see that for all the factors we could use the same values for description, actually the three states introduced already by Csíkszentmihályi (ibid): the *anxiety*, the *boredom* and the *Flow*. It is clear that the Flow is the highest value. But which is the worse of the two anti-experiences? – as Baracskai and Velencei (ibid, pp. 127-128) called the boredom and the anxiety. As we have already seen from the descriptions, if we are bored we still pay some attention and the transition between the boredom and the Flow was smoother than between the anxiety and the Flow. Thus, for this dissertation the anxi-

ety will be considered the worst value, the boredom is better, and, of course, the Flow is the best.

If we put the cognitive factor of attention into a function form, it will be similar to the learning capability, at least, at the first sight:

$$f(\Delta Q) \approx f\left(\underline{e}(\Delta Q), \underline{\dot{R}}(\Delta Q), M(\Delta Q)\right) \qquad [14]$$

The marking of the function *«f»* stands for Flow. As the actual variable of the function is the ratio of the new and the existing knowledge, it would be more accurate, to write the function in the following form:

$$f\left(\frac{\Delta Q}{Q_0}\right) \approx f\left(\underline{e}\left(\frac{\Delta Q}{Q_0}\right), \underline{\dot{R}}\left(\frac{\Delta Q}{Q_0}\right), M\left(\frac{\Delta Q}{Q_0}\right)\right) \qquad [15]$$

But we can consider the existing knowledge of the individual as a constant (at the beginning of a single process of knowledge increase); thus, henceforth the [14] will be used.

Now the other part of attention shall be examined, namely, the motivational factors. This part we start from the already restructured version of Maslow's hierarchy of needs and the different types of love. (see Section 3.6) The adapted form of Maslow's hierarchy has five levels:

- The *biological level* contains all the D-needs, so the physiological needs, the safety needs, D-love, D-cognition, and D-aesthetic needs.

- The *social level* contains all the social aspects, but here, as it was said earlier in this section, it is described solely with love.

- The *B-cognition* is the need to know and understand.

- The *B-aesthetic needs* are the need for harmonious, beautiful things – in the present case knowledge.

- The *self-actualization*, for this inquiry, also includes the transcendental needs.

The last three levels of motivation are the only ones that are really about knowledge increase. Therefore these will be considered as values of attention – for the knowledge increase. If we consider the social level only for a moment, it could be said that the different grades of satisfaction of the social needs will initiate the emergence of the higher needs. It is also coherent with Maslow's idea about the degree of relative satisfaction, i.e. that the degree of satisfaction of a lower need determines the emergence of a higher need.

If the social needs are not satisfied at all, there is going to be no attention at all. The lowest grade of satisfaction of social needs (as we will express it with love only) is the brotherly love, the *philos*. The higher *need to know and understand* will emerge if the social level is philos. The second grade of social needs is the *eros*, the erotic love, which has the precondition of philos (cf. Section 3.6). The corresponding emergent higher need is the *aesthetical* need. The highest grade of social needs is the *agape*, the love that consumes. Agape can often be detected in inspired work; the description of agape is very similar to description of flow or peak experience. The agape invokes the *self-actualization*.

It is worth taking a detour here to examine how the inspiration works. Many artists and scientists reported about their muses, who inspire them. Who is the Muse? Or what is a muse? It usually appears as a lover, so it should indicate the presence of eros. But the achievements associated with muses clearly point to agape. Muse is a metaphor of a lover, in whom eros and agape are united. It is also suggested by the flow experience or peak experience, described in perfect sexual acts. It seems that agape can be reached in some other mode as well, although most creative people report about muses.

The previous discussion would be valid if the attention depended on social needs only. It is easy to add the biological level. If the biological level was simply described with satisfied-unsatisfied grades, we could say that: (1) if the biological level is satisfied, the satisfaction at the social level determines the emergence of higher needs as explained above; and (2) if the biological level is not satisfied, the satisfaction at the social level will make no difference – the higher needs will not emerge.

This argument may seem crude but as the need to know and understand, the aesthetical needs and the self-actualization is on much higher level in the hierarchy than the biological needs, it actually does not contradict Maslow's (1954) original description. Assigning only two grades to the biological level might appear a weak point on a cursory glance. The reason for this is that we work in the framework of knowledge increase where the biological level is, in the vast majority of cases fairly satisfied, and thus, even a small deficiency of it appears as major dissatisfaction. The biological and the social level as explained here are two separate but interrelated factors and the higher levels would be the grades of the outcome.

The biological and the social needs can also be described using the form of functions, as it was done in the previous cases, and the functions are understood to have the properties as it has been described so far. The two functions are:

$$b(\Delta Q) = b(t(\Delta Q)) \tag{16}$$

$$s(\Delta Q) = s(t(\Delta Q)) \tag{17}$$

Where $t(\Delta Q)$ is the time when the knowledge increase happens, the biological and the social levels do not directly depend on the new knowledge, only through the time of knowledge increase. If the social level was described with all four dimensions, the situation would certainly be quite different.

The three described function constitute the function of ***attention***:

$$a(\Delta Q) = a\big(b(t(\Delta Q)), s(t(\Delta Q)), f\big(\underline{e}(\Delta Q), \underline{\dot{R}}(\Delta Q), M(\Delta Q)\big)\big) \tag{18}$$

The nature of this function was described separately for the cognitive factor and for the biological and social factor. All these will be merged together in form of logical rules in Section 7.4.

The need to know and understand, the aesthetical needs and the self-actualization are the grades of the attention. To create grades that reflect the domain of the knowledge increase better, we can borrow terminology from de Bono (1994. p. 116) while retaining the meaning. So, we can call the attention at the level of need to know and

understand it as *"analytical"* and the attention at the level of aesthetic needs as *"design"*; terms which were used by de Bono to describe different learning levels. If the two lower grades of attention are described by de Bono's notions, the logical highest grade would be the inspired learning and the *"inspired"* attention accordingly.

6.5. Learning Ability

The aim of this section is to bring together the previously introduced three models into a single one. If a person is willing to learn a particular new knowledge, is capable of learning it, and can pay attention to it, she/he learns it. This is, of course, true and meaninglessly oversimplified. Now a detour will be taken here to inquire into the nature of the delivery of new knowledge to have a better understanding for constructing the Model of Learning Ability.

If two individuals learn the same thing; they will not learn the *'same'*. There is a difference in the amount, when one person does not learn so much of the new knowledge as the other one; they do not understand the relations to the ***same depth***. This difference in amount is described by the learning capability. The same individual does not learn the same the new knowledge to the same depth on two different occasions; this is mostly due to attention she/he can pay to the new knowledge. On the other hand, there may also be a difference in quality, which is to say that the new knowledge will not have the ***same meaning*** to different individuals or to the same individual on different occasions.

When delivering new knowledge to someone, influence is used. If we want the new knowledge to have the same meaning for everyone, we *'influence to accept'*. That is the case with teaching elementary mathematics. There are situations, when it is not essential what meaning the new knowledge has to the person. In such a situation we do not typify the meaning of the new knowledge, we *'influence to think'*. Here the trivial instances are the pieces of art. Of course, in most of the cases we use a blend of the two pure influence types in our teaching. In our teaching in higher education we usually use 'influence to accept' for the basic concepts of a discipline,

and we use 'influence to think' about these concepts in business (or other) environments.

What happens during the transmission of the new knowledge that causes differences in the meaning to different persons? It is again about the cognitive schemata, although not about having the different number of schemata, but to have schemata of different content (i.e. difference of speciality, the expert biologist and the expert lawyer may have similar number of cognitive schemata, and these may be of similar complexity but their knowledge is still very different). The teacher encodes the new knowledge using her/his own cognitive schemata and the learner decodes it using her/his own ones. The similarity between the sent and the received knowledge may be increased by increasing the redundancy. If the new knowledge is explained in many different ways, the learner will be able to connect it to many different schemata or groups of schemata.

The differences can be completely eliminated only from the schemata of the well-structured world organized into simple hierarchies. The word-for-word memorizing of the text of a poem would belong here, while a beautiful counter-example would be the meaning and feeling of the poem to the person, who was learning it. The schemata forming those simple hierarchies are not worth investigation (it would be oversimplification of the reality), though they may be treated as the border-line cases of the muddled hierarchies. If the new knowledge is transmitted with high redundancy, and the learners are not amateurs (even better if they are experts), they are coming from similar related disciplines, it can be assumed that the new knowledge will have pretty much the same meaning to all of them.

If the previous train of thought is accepted, a new attribute can be created – based on the learning willingness, the learning capability, and the attention – which describes how the person absorbs the new knowledge. This attribute will be called the *learning ability*. The function of the learning ability is constructed from the functions

of learning willingness, learning capability, and attention;[1] *«d»* stands for docility, as *«a»* is already used for the function of attention:

$$d(\Delta Q) = d\left(w\left(V_{person}(\Delta Q), V_{org.}(\Delta Q), i(\Delta Q)\right), c\left(\underline{e}(\Delta Q), \underline{\dot{R}}(\Delta Q), M(\Delta Q)\right), a\left(b(\Delta Q), s(\Delta Q), f(\Delta Q)\right)\right) \quad [19]$$

This is really the function, which we would need instead of unknown *g(q)* in [8]; using learning capability was temporarily meant to have learning willingness and attentions as constants:

$$Q_1 = \int_{P_1} d(q)\,dq \quad [20]$$

It is possible to draw a picture of the learning ability, in similar way to the picture of the learning willingness. The axes can be assigned the same way as in case of learning willingness. The only difference in the outfit will be that the maximum of the learning willingness of different individuals was the same, while the learning ability of the person with the highest learning capability would be four times higher than in the case of the person with the lowest learning capability (if learning capability is described as logical relation with range of 4 values, and the attention is the same). The impact of attention could be described the same way.

We could say that the picture of the learning ability is obtained by stretching surfaces of learning willingness of each person in direction of *z*-axis in proportion of her/his learning capability and attention. (Figure 40) Of course, this picture is far from a satisfactory description but it is appropriate to grasp something of the behaviour of the function of learning ability, i.e. the picture is representational of the non-linearity of the function rather than being a model determined from specific data. Accurate description is given in Section 7.5 using logical rules in Doctus KBS. To keep the explanation simple, it only contains the impact of different learning capabilities of person *A* and person *B*; the impact of attention could be described the same way.

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[1] *Namely, from these we could assume if the three functions were known, though their functional relations producing the learning ability are unknown as well. Of course, again, this is not a function to calculate, only a picture.*
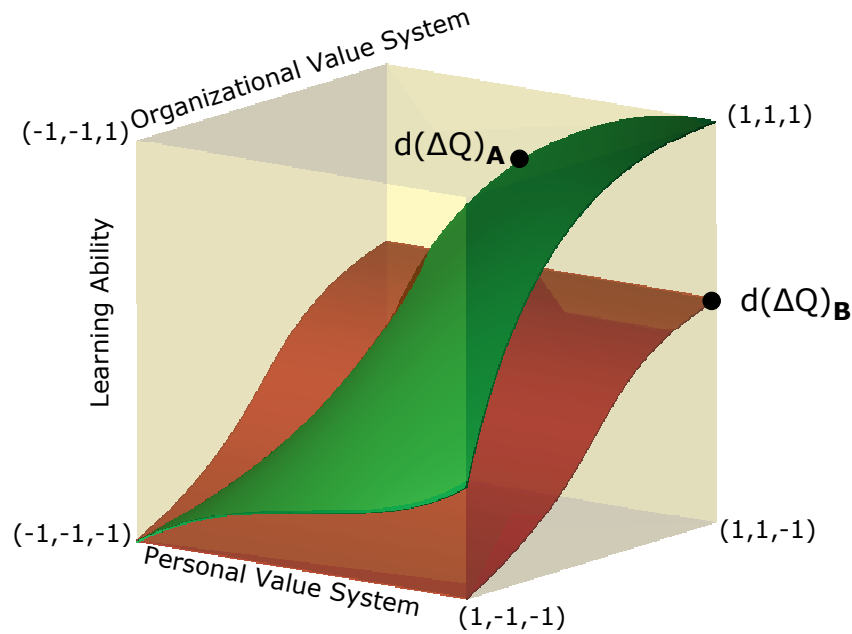
Figure 40: 3-D picture of the *Learning Ability*.

The example from Section 6.2 is extended on Figure 40. Person *A* (green surface) and person *B* (red surface) have different value systems; therefore they have made different judgements upon the same new knowledge. Their existing knowledge in the discipline also differs. Learning capability of person *A* for the new knowledge *ΔQ* is very high while of person *B* it is medium. In the value system of the organization the *ΔQ* new knowledge is «useful» (indicates plane through 1, i.e. the backside of the cube), in the value system of person *B* it is «promising» (indicating the line, which pierce the *xy*-plain at point (1,1) on the edge of the cube); in the value system of person *A* it is «neutral» (indicating the line, which pierce the *xy*-plain at point (0,1) in the middle of the backside of the cube). We could say that the learning capability has the stronger fitness than the learning willingness in this particular case. Namely, point *d(ΔQ)A* is higher than *d(ΔQ)B*, which means that learning ability of person *A* is higher; none the less his learning willingness was lower.

For those thinking in two-dimensional pictures, it would be easier to connect the top-view picture (Figure 41) to their existing knowledge. We can see that the green surface of person *A* has increased at the expense of red surface of person *B*, compared to Figure 31 in Section 6.2. It follows that (in the examined example) if a person is to be chosen to learn a particular new knowledge, it may be worth choosing

the more capable one, even if his judgement of the new knowledge is lower and he has shown to be weaker in following the organizational value system. Of course it may easily happen that $d(\Delta Q)_A$ falls onto the green surface and $d(\Delta Q)_B$ falls onto red surface, in which case the 2D picture is useless.
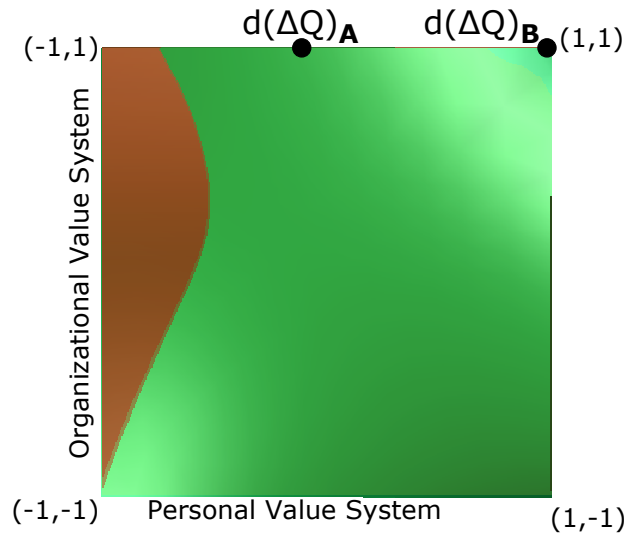
Figure 41: The *Learning Ability* model from above.

These graphical representations of MLA can be useful but it is not always convenient to use such pictures. A more convenient way of application is using expert systems, e.g. Doctus – as it is done in the next chapter.

In this chapter the four descriptive models were introduced. All of them were developed using mathematical symbolism but, although they appear in forms of functions, they are not calculable functions, only compact descriptions of a qualitative nature. Still, the use of the mathematical symbolism has more significant impact than keeping the descriptions compact: the nature of the used symbols suggested directions for this research, e.g. the derivation of the three basic variables of learning capability by time. There were also graphical presentations used for illustration, aiming to provide additional explanations about the nature of the models. The purpose of all forms of the descriptive models was to acquire better understanding of the learning process. The next chapter introduces another development of the present models; using simulative models. These are knowledge bases constructed on the basis of the descriptive models; they are used to test the hypotheses and they can also serve as real-life applications.

7. Simulative Models

> *"... room must be made for the experiences of essences and values; we must even recognize that essences alone enable us to classify and examine facts."*
>
> *Jean-Paul Sartre[1]*

The descriptive versions of the main results (namely the MLW, the MLC, the MA, and the MLA) were introduced in the previous chapter; in addition to the descriptive models, this chapter introduces what was until now referred to as 'simulative models' developed using the Doctus KBS.

As it is shown in this chapter, Doctus was used not as a simulation in the usual sense of the word[2] but as a way to put the ideas/hypotheses into executable form, so that they can be tested and fine-tuned. To do this, observed inputs were recorded and fed into the developed models throughout the research. (For this purpose the models were encoded as knowledge bases.) The outcomes from the models (i.e. knowledge bases) based on these real-life inputs were then compared to the observed outcomes. As this logic is the logic of thought experiments and Doctus' role is to formalize the process the appropriate term to describe this testing and fine-tuning would be "*formalized thought experiments*".

The formalized thought experiments were conducted with Doctus using the following steps[3] (Figure 42): First ideas/hypotheses[4] were developed based on observations (Section 2.6), literature, and, most of all, thinking about knowledge and knowledge increase, on conceptual work to date (i.e. in the early stage of the research). Then, a knowledge base (see Section 3.7 for general description, a more specific de-

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[1] *Sartre, Jean-Paul (1962) Sketch for a Theory of the Emotions, Routledge Classics, London, p. 7.*

[2] *Simulations use generated populations to test ideas/hypotheses; Doctus was used here to compare the ideas/hypotheses to observations and thought experiments.*

[3] *The details of the process are explained in Section 7.1.*

[4] *The term 'ideas/hypotheses' refer to the descriptive models in their early stage; the 'descriptive models' term refers to the final form.*

scription follows in Section 7.1) was constructed based on these ideas/hypotheses, and this knowledge base was used to make inferences about the 'cases', that is to say, to evaluate the learning ability of learners regarding a particular piece of new knowledge. The case features (input side) were defined on basis of observations and thought experiments (Sections 2.3 and 2.4). The evaluations of the cases from the knowledge base (output side) were compared to the observational outcomes and the inferences of the thought experiments. Based on the comparison, the ideas/hypotheses were accepted, refined or rejected; finally, after many iterations, those models, which are introduced in this and the previous chapter, were accepted. This also means that the testing of the ideas/hypotheses is not considered to be a means to verification (as it was shown to be impossible in Chapter 2) but an integral part of getting to the results.
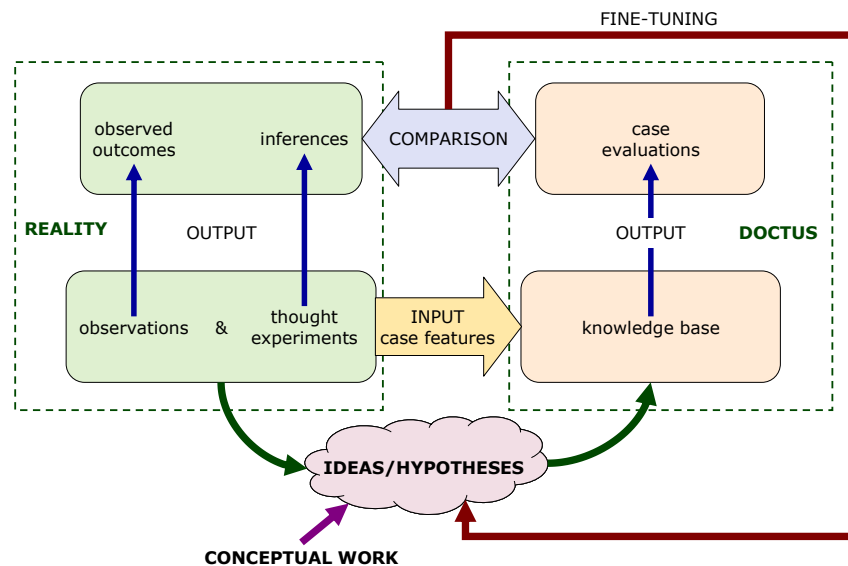
Figure 42: Refining ideas/hypotheses.

Once the knowledge base is accepted as valid (this means that the refinement is finished and the knowledge base is also customized for a particular organization, which is explained in the following four sections), it can also be used as a tool for evaluating cases for which we do not know the outcome. For even more convenient use, Doctus can export the knowledge base in easy-to-handle forms (not requiring knowledge of Doctus), such as an html page with on-page reasoning. (See Section 7.5) As it will be explained later in this chapter, to be used as a real-life application, the knowledge base will need to be customized for a particular organization (to re-

flect the value system of that organization). However, a real-life application was not the primary purpose of using Doctus; the primary purpose was the refinement of ideas/hypotheses. (See Chapter 2) The input for this refinement was taken from the "Apprenticeship School" introduced near the end of Section 2.4 and the inferences of Doctus were compared to the observed outcomes. So it could be said that the "Apprenticeship School" corresponds to «Reality» on Figure 42.

In this chapter, the first section explains how to 'put some knowledge' into Doctus, i.e. how a knowledge base is constructed; and then how it can be used for the evaluation of cases. Then four subsequent sections describe how the knowledge bases of the four models were constructed.

7.1. Doctus KBS

At the beginning of the present chapter it was explained very briefly *what* Doctus was used for in the present investigation; this section aims to show *how* it was done. First the ideas/hypotheses were developed, and these were then tested against cases, by means of knowledge base. Only the rule-based reasoning (RBR) of Doctus was used; therefore, only this will be described in detail.[1] The reason for using RBR rather than CBR is that in RBR it is possible to make use of conceptual work to a greater extent than in CBR. In CBR the conceptual work can only provide the attributes and nothing more; after that cases of experience are recorded and rules are induced to describe the cases. In RBR apart from the attributes their structure can also be derived from conceptual work and, at least on some occasions, values and the rules connecting these values. This also means that the CBR is more context dependant and thus its validity beyond the observational context is questionable.

This section first introduces the steps of building a knowledge base, explaining, in more precise way than in section 3.7, what constitutes a knowledge base. The end of

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[1] *The description of the other two ways of using Doctus, and also a more detailed description of RBR, can be found in the online documentation on the Doctus website. (Doctus website, n.d.)*

the section then focuses on how the particular knowledge bases of this research were built.

The easiest way to understand the RBR and the construction of the knowledge base is to start from its aim, which is to evaluate cases. In general, cases can be anything that we can describe from all relevant aspects;[1] in the present investigation the cases are the potential learners regarding a particular piece of new knowledge (for this dissertation this means a single cognitive schema). The forthcoming description follows the way how Doctus is usually used, which actually follows the logic of Simon's conception of bounded rationality (cf. Section 3.1).

As Doctus is an expert system, the elements of the knowledge base, are collected from the expert. For this research I was the expert[2]. Later in this section more details will be provided about how the knowledge base relates to the descriptive models from the previous chapter, for now the only aim is only to provide satisfactory explanation what the knowledge is and how it is constructed in general terms.

A knowledge-based system consists of two main parts, the shell (the software package) and the knowledge base. The first step of building a knowledge base is to define aspects of the evaluation, i.e. the *attributes* and their *values* (cf. Section 3.1); the attributes with their values constitute the first element of the knowledge base. The outcome of the evaluation is also an attribute and its values are the possible outcomes. Figure 43 shows the *«Attributes»* pane of Doctus[3], which is the interface for defining the attributes and their values; here it contains the attributes and values of the Model of Learning Ability[4].

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[1] *If the cases are not described from all relevant aspects the knowledge base will fail to provide proper evaluation of the cases.*

[2] *As it was explained in Section 6.3, for the MLC the attributes and their values were first acquired from Zoltán Baracskai, but the next day I have arrived to the same results applying mathematical tools to the systemic model of knowledge. More details follow in Section 7.3.*

[3] *The Excel-like look-and-feel of this surface is intentional, i.e. the familiar screen is supposed to facilitate the user experience.*

[4] *Here it is only a picture, showing what the attributes and values look like in Doctus; how these attributes and values were arrived at, is described in Section 7.5. Similarly, all the figures in the present section only serve this purpose.*

Figure 43: Attributes and values in Doctus.

The number and the order of values is up to the expert; here the values are in *'first the worst'* (also called *«increasing»*) order for every attribute; e.g. on Figure 43 for *«Learning Willingness» «reluctant»* is the worst value, *«accept»* is better, and *«require»* is the best.[1] The second step (and the second element of the knowledge base) is to structure the attributes into a hierarchy called the *Rule-Based Graph* (RBG). (Figure 44 shows the RBG of the MLA.) The reason for structuring the attributes, as explained in section 3.7, is that the experts cannot connect too many values into a single rule due to the limited capacity of STM.[2] (cf. Section 3.4) For example, on Figure 44 we have 14 input attributes (the leaves of the graph) which would certainly be too many to handle; therefore they are structured into a four-level hierarchy. The structure of the RBG should follow the cognitive structure of the expert (actually it cannot be otherwise if it is assumed that the attributes and their structure are acquired from the expert); as it will be shown later in this section, that in this particular research the structure naturally evolved.

[1] *For the moment it is not intended to explain how these attributes and values were arrived at, only what they look like in Doctus. A general description about the origin of these (and of the other elements of the knowledge base) is given at the end of this section, more detailed account about the origins of the elements for the particular knowledge bases is give in the forthcoming four subsequent sections.*

[2] *Our (meaning the research group of Zoltán Baracskai) consulting and teaching experience tells us that the number of attributes connected into a single node should be kept at 3-4.*

By constructing a RBG, the inference is converted from a single-step into a multi-step reasoning; this means that the inference goes from the leaves of the graph towards the root, which is the output attribute. Using an example from Figure 44 *«Schemata»*, *«Speed»*, and *«Meta-schemata»* determine the *«Learning Capability»*, and the *«Learning Capability»*, together with the *«Learning Willingness»* and *«Attention»* determines the *«LEARNING ABILITY»*. The attributes on which another attribute depends are the *factors* of that attribute; e.g. *«Schemata»*, *«Speed»*, and *«Meta-schemata»* are the factors of *«Learning Capability»*; and the attributes having factors are the *dependant attributes*. The definitions of the attributes and values and the construction of the RBG, in real-life applications, usually go in parallel; the expert has a better overview of the attributes when they are structured into RBG. The RBG can also be used to display various information, e.g. on Figure 44 it displays the values for each attribute.
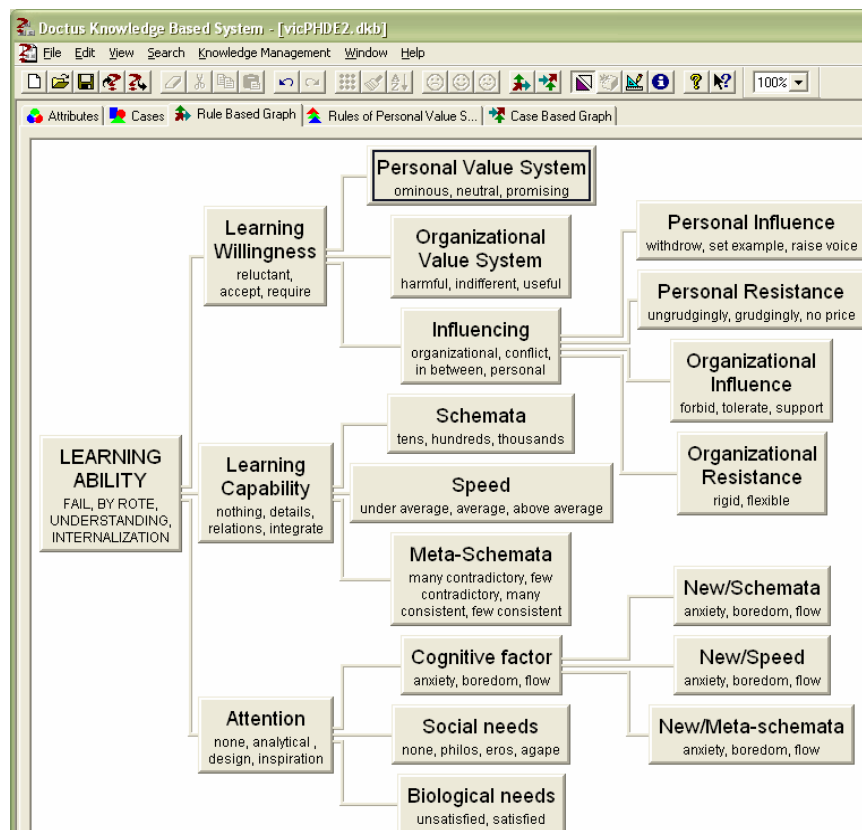
Figure 44: Rule-Based Graph in Doctus.[1]

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[1] *Some of the figures in this section will appear again in the forthcoming sections. The reason for this is that, on the one hand, it is easier to follow a description if there are figures in*

The RBG shows *which* the factors of each dependant attribute are but it does not say *how* a dependant attribute is determined by its factors. To answer this 'how' question, the expert defines a set of rules in each node of the RBG (each dependant attribute) by connecting the values of the factors; the rules constitute the third element of the knowledge base. The rules are logical statements in *«if… then»* form connecting the values of the factors in each node. If a rule connects one value of each factor of the node it is called an *elementary rule*; if we merge two or more elementary rules, we get a *complex rule*. In a complex rule for at least one of the attributes more than one value is used (see examples later).

There are two ways of displaying rules in Doctus, and they can also be defined in both views: The *rule list* (also called *one dimensional* or *1D view*) is the seemingly simpler way; in this view a column is assigned to each factor and we put the particular values into the cells in the column, until all value combinations of the factors are covered. The last column is the rule output to which we assign values of the dependant attribute. If we want to define a complex rule, we can define ranges of values. E.g. the first rule on Figure 45 reads:[1] *'If the «Attention» is «none» then whatever the «Learning Willingness» and the «Learning Capability» are, the «LEARNING ABILITY» is «FAIL»'*; and the last rule reads: *'If the «Learning Willingness» is «require», the «Learning Capability» is «integrate», and the «Attention» is «analytical or better» then the «LEARNING ABILITY» is «INTERNALIZATION»'*.

Learning Willingness	Learning Capability	Attention	LEARNING ABILITY
*	*	none	FAIL
reluctant	*	*	FAIL
*	nothing	*	FAIL
accept	details	analytical ..	BY ROTE
accept ..	details	analytical	BY ROTE
require	details .. relations	design ..	UNDERSTANDING
accept ..	relations	analytical ..	UNDERSTANDING
accept	relations ..	analytical ..	UNDERSTANDING
require	integrate	analytical ..	INTERNALIZATION

Figure 45: Complex rules in rule list (1D) view of Doctus.

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place for illustration (so there are no references to figures located several pages away) and, on the other hand, it does not make sense to use a different example.

[1] *The full range (any value) is marked with "*".*

Most of the users find it more convenient[1] to use the *two dimensional* or *2D view*. In 2D view the values of the factors are arranged into row and column headings and thus each cell in the table is an elementary rule. (Figure 46) The two rules previously read from Figure 45 (1D) can also be read from Figure 46 (2D): the first rule from the previous paragraph is indicated with the four blue rows and the second rule is shown in the red range.

Figure 46: Rules in 2D view of Doctus.

Now we have the attributes with their values, their structure, and the rules defined, so the knowledge base is ready for use. The final step is to describe the cases (Figure 47), and then, to trigger the rules – and we have the evaluation. To describe the cases we have to define the *case features*, i.e. for all cases the expert assigns one value (selecting one of the previously defined values) of each input attribute that characterizes that case. When the case features are defined the rules can be 'fired' to get the output values, i.e. the evaluations of the cases. The evaluation can be displayed on the *«Rule-Based Graph»* or on the *«Cases»* pane, on Figure 47 they can be found in the first row; the case features are described in the subsequent rows, and each column corresponds to a case.

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[1] *Based experience with dozens of users in consultancy and hundreds of students on computer lab sessions.*

Figure 47: Cases in Doctus.

The description provided so far assumed the knowledge base being built on basis of expert opinion; the aim was to clarify the terminology, explain the elements of knowledge base as well as the steps of building it. In the remaining part of the section a rationale is provided about how the knowledge bases relate to their descriptive versions. Here this is done in general terms only, more detailed explanation about the particular models/knowledge bases are provided in the forthcoming four sections.

In the previous section the four descriptive models were displayed in form of functions, which cannot be calculated but provide qualitative description of the models. There were also examinations of these functions resulting in explanations about the nature of the function, and these were supported by function-like figures. At the beginning of this section it was said that the structure of the knowledge bases in the present research "naturally evolved". This is shown on Figure 48: the variables of the function are the factors of the dependant attribute.
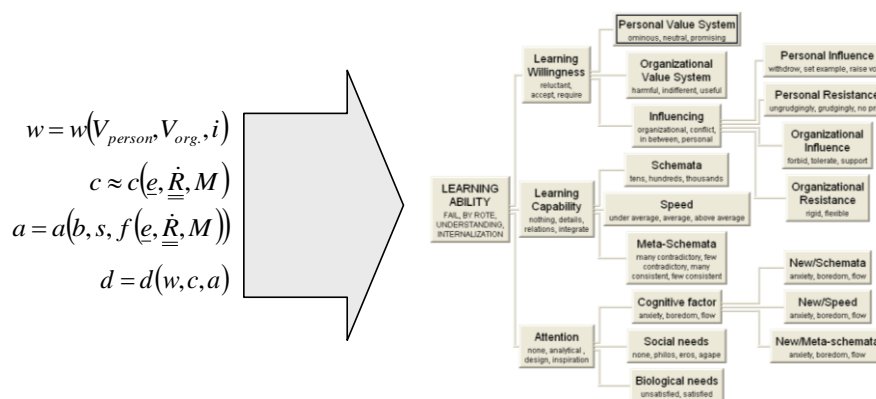
Figure 48: From descriptive models to knowledge bases.

The functions are abbreviated for the shorter description (the independent variables of the function, i.e. the «ΔQ»'s, are not included). The four functions are subsequently the MLW [2], MLC [13], MA [18], and the MLA [19]. The variables of the last function are actually the preceding three functions, meaning that the factors of *«LEARNING ABILITY»* are the *«Learning Willingness»*, the *«Learning Capability»*, and the *«Attention»*. The remaining factors can be determined in a similar way from the other three functions. This means that the attributes and their structure were determined during the conceptual work and the observations and thought experiments (as it was shown on Figure 42 at the beginning of the chapter); the descriptive models in form of functions provide the complete structure. Most of the values were also determined during the development of ideas/hypotheses; separate account is given about these in the forthcoming four sections, separately for each model. The examination of the functions (including the figures) served as starting point for determining the rules – these will also be explained separately for each model.

By building the knowledge base we got an executable form of the ideas/hypotheses, which was used to test and refine these ideas/hypotheses. Besides, we also got a useful application, which can be used to evaluate potential learners regarding a particular piece of new knowledge. There are, however, limitations to the application usage. The rules reflect the observations and thought experiments based on which they were defined; thus, for application in a different environment they need to be re-defined to reflect the particular organization. The names of the attributes and values may also be modified to reflect the organizational language.

The forthcoming four sections describe the knowledge bases of the particular models; the fourth knowledge base is the integration of the first three the same way as the fourth descriptive model (MLA) was the integration of the first three descriptive models in the previous chapter.

7.2. The Knowledge Base of the Learning Willingness

The previous work done about the learning willingness includes Section 4.2.9 and Section 6.2. The present section uses the findings from these two previous sections to build a simulative model.

In Section 6.2 the learning willingness was modelled depending on the two value systems, namely the individual and the organizational, and their mutual influence; therefore the function of learning willingness has three variables: the organizational value system's judgment about the new knowledge, the personal value system's judgment about the new knowledge and the mutual influence of the two value systems. This was shown in function [2], which is in abbreviated form: $w = w\left(V_{person}, V_{org.}, i\right)$. The third variable is a function of functions itself, depending on personal and organizational influence and resistance; as shown in function [1], which is in abbreviated form: $i = i\left(I_{person}, I_{org.}, R_{person}, R_{org.}\right)$[1]. The structure of the attributes for the knowledge base of the learning willingness is directly provided by these functions, as it is shown on Figure 49; the figure also displays the values of the attributes, these are described in the following paragraphs.
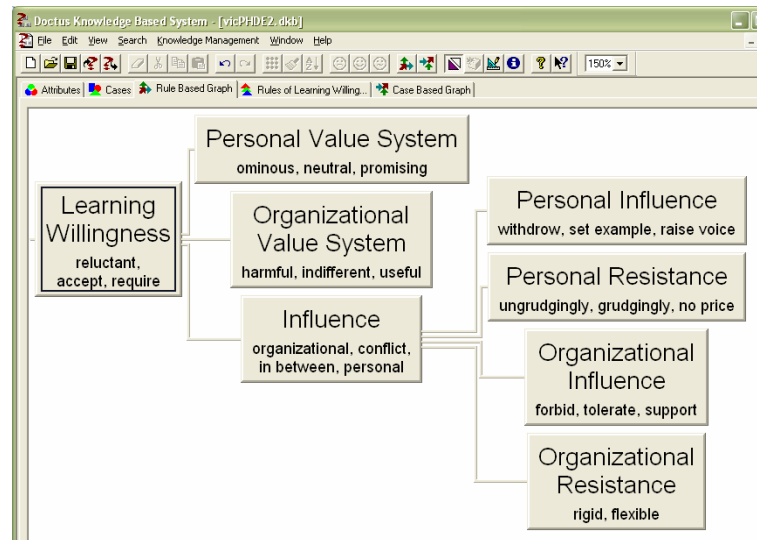

Figure 49: Factors of learning willingness.

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[1] *The role of the external players, called "mentor" and "environment" in Section 6.2, are not included in this abbreviated function and consequently they are not included in the knowledge base. The implications are reviewed later in this section.*

The value of new knowledge was described in Section 4.2.9 from the viewpoint of both the individual and the organization. The values for the two attributes, i.e. the possible judgments about the new knowledge from the individual and the organization, were described: for the individual the new knowledge may be *«ominous»*, *«neutral»*, or *«promising»*, for the organization it may be *«harmful»*, *«indifferent»*, and *«useful»*. The meta-judgments in terms of influence and resistance to influence were also described:

- Values of personal influence: *«withdraw»*, *«set examples»*, and *«raise voice»*.

- Values of personal resistance: *«ungrudgingly»*, *«grudgingly»*, and *«no price»*.

- Values of organizational influence: *«forbid»*, *«tolerate»*, and *«support»*.

- Values of organizational resistance: *«rigid»* and *«flexible»*.

The values for the *«Influence»* and the *«Learning Willingness»* were decided on basis of the observations and thought experiments, i.e. they were not deduced on conceptual basis. There were four values observed for the *«Influence»* and recorded into the knowledge base, namely:

- *«organizational»*, meaning that the organizational judgment of the new knowledge is accepted,

- *«conflict»*, meaning that there will be a conflict between the individual and the organization,

- *«in between»*, meaning that there will be a compromise found between the individual and the organizational judgment of the new knowledge, and

- *«personal»*, meaning that the personal judgment of the new knowledge is accepted.

Similarly, there were three values observed and recorded into the knowledge base for the *«Learning Willingness»*, namely:

- *«reluctant»*, meaning that the person tries to avoid to learn the new knowledge,

- *«accept»*, meaning that the person accepts the new knowledge but is not proactive to acquire it, and

- *«require»*, meaning that the person is eager to learn the new knowledge.

Having defined the rules for these two attributes in this way also means that the values reflect the observational circumstances, i.e. in another organization there might be different values. This is true and necessary, although it limits to some extent the validity of the knowledge base. For example there may be an organization in which being *«reluctant»* is an unacceptable behaviour and if anyone behaves so is fired, in which case it may be reasonable to include *«fire»* value instead of *«reluctant»*; in another organization both values may be relevant. It is also possible to use different names for the values simply to adapt the knowledge base to the organizational language.

There are two dependant attributes in this knowledge base (the *«Learning Willingness»* and the *«Influence»*, see Figure 49) and there are correspondingly two sets of rules. Both rule sets are based on observations and thought experiments. This means that some rules were directly observed but these, naturally, do not cover all the possible value combinations; so for the missing value combinations thought experiments were carried out, that is to say, thinking about 'what would happen if…' to cover the missing rules. It is a necessity to have rules reflecting the observational situation, which means that they reflect how things happen in the particular organization. As both rule sets deal with highly organization-dependant relations, both rule sets need to be customized to the particular organization that we want to describe.

Figure 50 shows the rules of *«Influence»* in a form of complex rules in 1D view. Here, for instance: *'If the «Personal Influence» is «set example», the «Personal Resistance» is «grudgingly», the «Organizational Influence» is «support», and the*

«Organizational Resistance» is «flexible», then the «Influence» is «in between».' In another organization the same value combination on the input side may result in *«personal»* for *«Influence»*. This suggests that the rules have to be customized.

Figure 50: Complex rules of influence in 1D.

Figure 51 shows the rules of *«Learning Willingness»* in 2D view; similarly to the rules of *«Influence»*, these must be modified to fit the particular organization. A convenient way is to show the knowledge base with these values and rules as a prototype, and then delete the rules and start from having the structure, while the values can be changed along the way.

Figure 51: Complex rules of learning willingness in 2D.

To summarize, the values may or may not be different for different organizations; if the members of the organization can accept the terminology, there is no need to change the names of the attributes and values. It is most likely that the values that were chosen on observational basis (i.e. for *«Influence»* and for *«Learning Willingness»*) will be modified. It is also possible that an organization wants to have different number of values for the attributes for which the values were defined on concep-

tual basis; this does not mean that the presented values are not appropriate but e.g. an organization may want to distinguish more shades of *«harmful»* new knowledge. In this knowledge base the rules are highly organization-dependant and thus they must be customized.[1] Nevertheless, the present ones can be used for prototyping purpose. (Cf. Section 7.1).

Contrary to the values and rules, the structure of the attributes is not likely to need any changes; the reason for this is that the models are not only based on observations but also on conceptual work, namely on function of learning ability from Section 6.2, thus they are supposedly more general.

What is not taken into account in the knowledge base is the influence of the external players. As it was explained in Section 6.2, the external players directly affect the judgement of the person or the organization, therefore this influence can be considered by changing the values of judgment for the individual and/or the organizational value system according to the influence.

7.3. The Knowledge Base of the Learning Capability

The descriptive version of the MLC was developed in Section 6.3 using virtually the whole of Chapter 4 and several sections from Chapter 3 as its basis. Section 6.3 modelled the role of existing knowledge in the knowledge increase; the present section uses the findings of that section to build a simulative model.

When constructing the descriptive model, the learning capability was modelled on basis of a systems model of knowledge. There were three characteristics considered, the elements of the systems (these were defined as the cognitive schemata), the relations between the elements, and the structures (these were identified with the meta-schemata). As the process of knowledge increase happens in time, the three basic variables were derived by time, resulting in six variables but three were shown to be negligible. This resulted having three factors of learning willingness, the number of

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[1] *It will be shown in the forthcoming three sections that for the remaining three models the rules are more general.*

schemata, the speed of changing relations between the cognitive schemata, and the meta-schemata.[1] This was shown in function [13], which is in abbreviated form: $c \approx c\left(\underline{e}, \underline{\dot{R}}, M\right)$. The structure of the attributes for the knowledge base of the learning capability can be directly read from this function; it is shown on Figure 52. As none of the variables are functions of functions, the RBG is single-levelled.
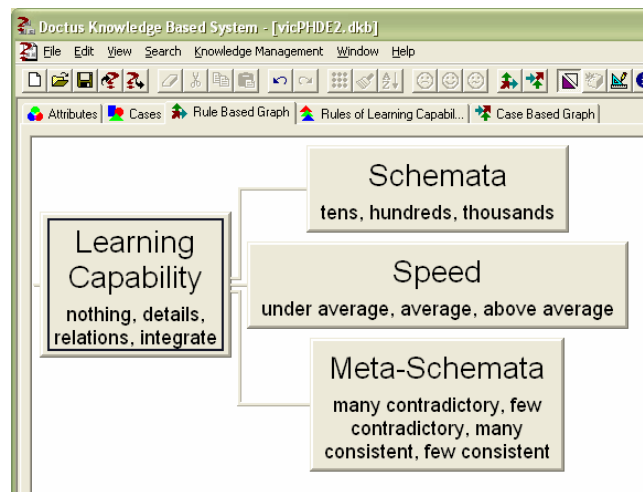

Figure 52: Factors of learning capability.

The values for the three factors were also determined in Section 6.3 by examining the behaviour of the three factors; for these examinations two factors were always considered constant and the learning capability was displayed as if depending only on one variable.

For *«Schemata»* the values indicate the number of schemata at different knowledge levels where the (grand)master is excluded[2]; thus the number of schemata may be *«tens»*, *«hundreds»*, or *«thousands»*.

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[1] *It was described in Section 6.3 the factors were first acquired from Baracskai and the next day the same results were obtained using strict mathematical-like logical deduction based on the system-model of knowledge. Here it could be added that the values and the rules were also acquired the same ways; however, for the sake of easier description, in the present section only the logical deduction is used as the starting point. From the standpoint of the outcome the two ways are equal.*

[2] *It was shown in Section 4.2.8 that the knowledge and the knowledge increase of the (grand)master fundamentally differ from the others'.*

For *«Speed»* the values are arbitrarily taken; it is the common way of assigning values when we do not have much reason for specific names: *«below average»*, *«average»*, and *«above average»*.

For *«Meta-schemata»* the values are not self-explanatory they were introduced in Section 6.3 and in Section 6.4 additional explanation was provided why these should be chosen, and why this is the (increasing) order: *«many contradictory»*, *«few contradictory»*, *«many consistent»*, and *«few consistent»*.

The values of *«Learning Capability»* are the typical values of knowledge bases; they are directly based on observations and thought experiments, meaning that the observed values were directly recorded into the knowledge base and then thought experiments were carried out to inquire if there are other possible outcomes:

- *«nothing»* means that the person is not capable of learning any of the new knowledge;[1]

- *«details»* meaning that the learner may get fragments of the delivered knowledge, may be able to repeat them but they are out of context;

- *«relations»* meaning that apart from learning the fragments the learner also understands some relations between these fragments but the delivered knowledge does not frame up into a whole;

- *«integrate»* meaning that the learner fully integrates the new knowledge with her/his existing knowledge, it forms a whole, and is placed into context.

As the structure of the attributes is result of logical deduction it does not need to be modified for a particular organization if we want to use the knowledge base. The situation is the same for the values. The only modification that would make sense is if one wants to use different terms (for attributes and values) that one is more com-

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[1] *This value was not observed in the Apprenticeship School; it is based on a previous experience of mine: I participated in a seminar in quantum physics; I understood everything there but even after an hour I could recall almost nothing I heard. In this case I was missing consistent meta-schemata, i.e. structures to which the new knowledge could be connected to. Similar examples can be quoted for the low speed and the low number of schemata.*

fortable with; e.g. if one wants to replace the *«hundreds»* in *«Schemata»* with *«advanced»* there is no harm done.

The last element for this knowledge base is the rule set. Here the rules were defined on basis of conceptual work shown in Section 6.3, more precisely, on the examination of the three factors (see Figure 33, Figure 34, Figure 35). This process can be envisaged as if the three figures were put together in a form of logical rules. (Figure 53) These were, of course, compared to the observations and thought experiments but in this case there was not much fine-tuning needed. The conceptual work was robust and the developed rules do not organization-specific; i.e. this model exclusively deals with the existing personal knowledge of the individual, that is to say, her/his knowledge at the beginning of the process of knowledge increase. Thus the observations and thought experiments were all covered. This also means that the rules do not need to be customized, apart from the already mentioned use of terminology.

	Schemata	tens	hundreds	thousands
Meta-Schemata	Speed			
many contradictory	under average	nothing	nothing	nothing
many contradictory	average	nothing	nothing	nothing
many contradictory	above average	nothing	nothing	nothing
few contradictory	under average	nothing	nothing	nothing
few contradictory	average	nothing	details	details
few contradictory	above average	nothing	details	details
many consistent	under average	nothing	nothing	nothing
many consistent	average	nothing	details	relations
many consistent	above average	nothing	details	relations
few consistent	under average	nothing	nothing	nothing
few consistent	**average**	nothing	relations	integrate
few consistent	**above average**	nothing	relations	integrate

Figure 53: Complex rules of learning capability in 2D.

There might be rare occasions that one would change the rules, not because they are not valid, but because the particular organization needs more or fewer outcome values, i.e. more shades of learning capability. In this case it is better if we hire an expert in the field of knowledge than to try customizing the knowledge base by ourselves.

7.4. The Knowledge Base of the Attention

The descriptive version of the MA was introduced in Section 6.4 based on the previous preparatory work done in Sections 3.5 and 3.6. The preparatory work included the restructuring of Maslow's model of motivation; the physical and safety needs were pulled together into a level named 'biological', and the belongingness and esteem needs were merged into a level named 'social'. The rationale for this was given in Section 6.4 and a limitation was also acknowledged, namely that the social level in the restructured version of Maslow's hierarchy of needs is described with love only and the other dimensions (power, money) are neglected. This previous work was done with regard to the motivational conditions of attention; apart from the motivational part, the Flow experience was used to describe the cognitive factors of the attention (Section 3.6). The Flow, as adopted in this research, is also a restructured version of the original one; i.e. the Flow model was described by the number of schemata, the speed and the number of meta-schemata. This can be regarded as three projections of the flow model on three cognitive planes (Section 6.4).

Based on the conceptual preparatory work, the attention was modelled in Section 6.4 depending on three the biological, the social and the cognitive factors. This was shown in function [18], which is in abbreviated form: $a = a(b, s, f)$. The third variable is a function of functions itself, depending on the number of cognitive schemata, the speed, and the number of meta-schemata; as shown in function [15], which is in abbreviated form: $f = f(\underline{e}, \dot{\underline{R}}, M)$. Although this function looks the same in this abbreviated form as the function of learning capability, they are not the same: the variable of the function of learning capability is the existing knowledge (ΔQ) and the variable of the cognitive factor of attention is the ratio of the new and the existing knowledge ($\dfrac{\Delta Q}{Q_0}$). The structure of the attributes for the knowledge base of attention is directly provided by these functions, as it is shown on Figure 54.
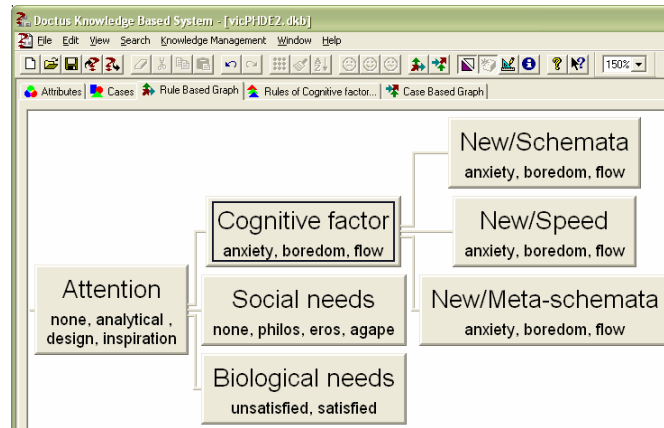
Figure 54: Factors of attention.

The values for the factors of attention were described in Section 6.4. It was argued that two values are sufficient for the biological needs, as for knowledge workers these are usually *«satisfied»* and, being D-needs (Section 3.6), they will have no influence in that case; on the other hand, if they are *«unsatisfied»*, nothing else will matter, the learner will not be able to pay any attention. (We can see, that here we already acquired some rules as well.) The social needs, as they were described by love only, have four values: *«none»* indicating the lack of love; and the three types of love, *«philos»*, *«eros»*, and *«agape»*. The values for the cognitive factor and its sub-factors are the same (the states originally introduced by Csíkszentmihályi): *«anxiety»*, *«boredom»*, and *«flow»*. The reason for this is that, as it was already said above, these sub-factors can be regarded as projections of the cognitive factor on three cognitive planes. Finally, for the values attention two are borrowed from de Bono, the *«analytical»* and the *«design»*; adding to these one value to each end, *«none»* on the lower end (i.e. the previous two values supposed that there is attention) and *«inspiration»* on the high end. The «none» value is probably obvious and the other is consistent with the descriptions of the "Flow state" or the "peak experience" described in Section 3.6.

It was already indicated that some rules are also based on conceptual work. For the cognitive factor the complex rules here are very simple, which is based on the nature of the cognitive sub-factors, i.e. that they are projections of the cognitive factor to different planes (Figure 55): If any of the factors is *«anxiety»* then the *«Cognitive factor»* is *«anxiety»*. If all factors are *«flow»* then the «Cognitive factor» is *«flow»*. In

all other cases (i.e. if none of the factors is *«anxiety»* and not all of them are *«flow»*) the *«Cognitive factor»* is *«boredom»*. Three rules only.

	New/Meta-schemata	anxiety	boredom	flow
New/Speed	New/Schemata			
anxiety	anxiety	anxiety	anxiety	anxiety
anxiety	boredom	anxiety	anxiety	anxiety
anxiety	flow	anxiety	anxiety	anxiety
boredom	anxiety	anxiety	anxiety	anxiety
boredom	boredom	anxiety	boredom	boredom
boredom	flow	anxiety	boredom	boredom
flow	anxiety	anxiety	anxiety	anxiety
flow	boredom	anxiety	boredom	boredom
flow	**flow**	anxiety	boredom	flow

Figure 55: Complex rules of cognitive factor in 2D.

The situation is similar for the rules of *«Attention»* too (Figure 56); it can be described by a few rules: The last three rules from the table could be formulated as a single rule: If any of the factors is at its worst value, the *«Attention»* is *«none»*. This results directly from the conceptual work, i.e. from the examination of the nature of attention. It is also easy to see that the best value of attention, the *«inspiration»* can only be achieved in *«flow»* feeling *«agape»* and having, of course, *«satisfied»* biological needs; this comes from the descriptions of peak experiences and agape as well. If this is accepted, it is also clear that the *«flow»*, *«eros»*, *«satisfied»* value combination cannot result in better than *«design»* for *«Attention»*; and we also do not have reason to assume that it would be lower, this is also what the observations suggest. It is less obvious, but still fairly arguable, that the *«boredom»* with at least *«philos»* and *«satisfied»* biological needs will result in *«analytical»* attention. Such a person could perform much better if could be pushed into the *«flow»* state, so it is worth examining which cognitive factor causes the boredom, sometimes this is really easy to help with, e.g. a slight increase of the pace of delivery (if the boredom was caused by the speed and the other two projections are *«flow»*) of the new knowledge may dramatically enhance the performance. The last rule, the *«flow»*, *«philos»*, *«satisfied»* combination, was neither covered by the conceptual work, nor was it observed. It is possible that it would be an impossible situation; i.e. that one cannot be in

«flow» if one is in *«philos»* only.[1] For the sake of completeness this rule was indicated *«analytical»* here.

Figure 56: Complex rules of attention in 1D.

In the knowledge base of attention, apart from the structure of the attributes, all the values and nearly all rules were derived on conceptual basis; and they are also meeting the observations. The process of arriving at this very neat state was not as straightforward as explaining it with hindsight. The conceptual work and the comparison of the observations and the thought experiments to the inferences of the knowledge base were iterative, just as it was said in Section 7.1.

As it must be acknowledged, that the restructuring of the models used in this modelling process could have been done in a different way (or not done at all) it also must be said that a different starting model could result in a different structure of attributes and different knowledge base. However, this does not mean that such a result would not be coherent with the present one, on contrary, as the conceptual work on which the knowledge base is based is robust, differently prepared starting point should result in a knowledge base coherent with the one presented here. Similarly to the previous knowledge base this model is not organization-specific (the case features that we put in may well be!) thus there is only one reason to change the attributes and values (if the present starting point is used), i.e. if want to use a different, more familiar terminology.

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[1] *This is my opinion but it is not more than an idea. Since the construction of the model I am paying attention to record if I observe or experience myself such situation but I have seen none yet.*

Now the knowledge bases of the three component models are ready to be integrated into the knowledge base of *«LEARNING ABILITY»*. Of course, they were in a single knowledge base all the time, only so far the particular branches of it were used.

7.5. The Knowledge Base of the Learning Ability

The MLA is formed from the integration of the previous three models, as was shown in Section 6.5 when its descriptive version was introduced. This model can be regarded as an answer to the problem as stated, after long preparation, in Section 5.3. The descriptive model of learning ability was meant to provide better understanding of how people learn and the simulative model makes the connection to the reality. In Section 6.5 the learning ability was modelled depending on three factors, namely the previously introduced three component models: the Model of Learning Willingness, the Model of Learning Capability, and the Model of Attention. This was shown in function [19], which is in abbreviated form: $d = d(w, c, a)$. The three variables of the function of learning ability are the three previously used functions ([2], [13], [18]), and all of them are functions of functions as it was described in the previous three sections. The structure of the attributes for the knowledge base of learning ability is directly provided by these functions; the result is the four-level RBG shown on Figure 57.

The values of the factors of learning ability were explained in the previous three sections, only the values of the root, of the outcome attribute *«LEARNING ABILITY»* remain to be explained. The situation is the same for the rules, i.e. only the rules in the root-node are not yet introduced.
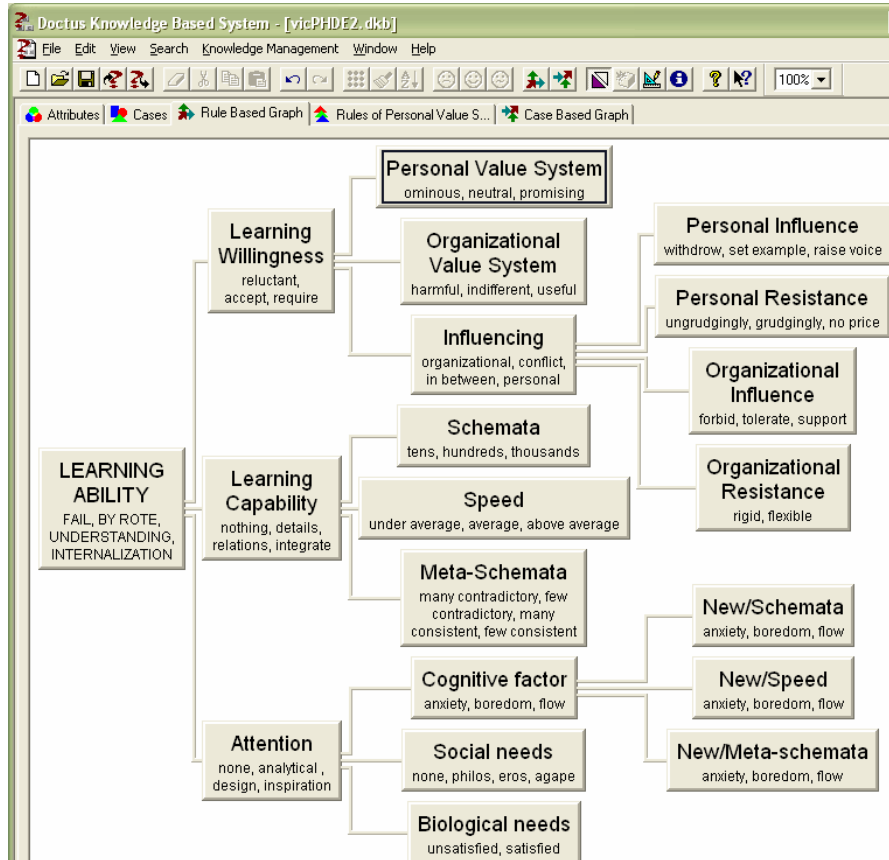
Figure 57: Hierarchy of attributes of learning ability.

The learning ability could be examined using the same logic as in Sections 6.3 6.4 when examining the MLC and the MA; i.e. to consider the learning ability as depending on one factor only while keeping the two other factors constant. This is the logic behind the illustration at the end of Section 6.5, when the 'cube' from Section 6.2 was adapted as being stretched by the other two factors. This logic can also be used for the other factors; one of these is used to determine the values of *«LEARN-ING ABILITY»*. For this the *«Learning Capability»* is considered variable and the other two factors constant. The interpretation of this is if we regard the learning ability being the realized learning capability; i.e. what learning capability of the person is described and we examine what is realized of it in situations characterized by different attention and learning willingness levels. But why the learning capability and not the other two factors? The reason for this is that the learning capability and the learning ability are similar with regard to the outcome, meaning that both models signify the level of acquiring new knowledge – actually this is meant by saying that the learning ability is the realized capability. Using this starting point the values of learn-

ing ability should be similar as the values of learning capability; but they should not be exactly the same to avoid confusion. Here the values of learning ability were chosen as synonyms for the values of learning capability:

- *«FAIL»*, meaning that the learner fails to acquire the new knowledge; the corresponding value of learning capability was *«nothing»*;

- *«BY ROTE»*, meaning that the learner is able to repeat some pieces of the delivered new knowledge without understanding them; the corresponding value of learning capability was *«details»*;

- *«UNDERSTANDING»*, meaning that the learner understands how the acquired details relate to each other and successfully connects these details to her/his existing knowledge but this new knowledge is not placed in context, it does not form new structures with the existing knowledge; the corresponding value of learning capability was *«relations»*;

- *«INTERNALIZATION»*, meaning the highest level of acquiring new knowledge, it becomes part of the existing structures and also form new structures with the existing knowledge; the corresponding value of learning capability was *«integrate»*.

It must be admitted that this line of thought is far from trivial but there is no mistake made in the logic. Comparing the inferences to outcomes of numerous observations and thought experiments the values did not fail. This, of course, cannot be accepted as a justification according to the approach of this dissertation (Chapter 2) can be considered as a sign of being on the right track. To be faithful to the research process, it also must be admitted that the order of steps was not the same in which they were presented: first the values were defined as temporary ones, intending to change them during the refinement; then it was found that they neatly corresponded to the observations and thought experiments; finally the relation between the learning ability and the learning capability was recognized.

The logic according to which the values of learning ability were presented can also be used to explain the rules. On Figure 58 the *«Learning Capability»* is shown

as a column header, the other two attributes are on the left side as row headers. Starting from this picture, the rules can be regarded as 'shifting' the values of *«Learning Capability»* with the values of *«Learning Willingness»* and *«Attention»*, which process correspond to realizing the learning capability from the previous explanation.

Learning Willingness	Learning Capability Attention	nothing	details	relations	integrate
reluctant	none	FAIL	FAIL	FAIL	FAIL
reluctant	analytical	FAIL	FAIL	FAIL	FAIL
reluctant	design	FAIL	FAIL	FAIL	FAIL
reluctant	inspiration	FAIL	FAIL	FAIL	FAIL
accept	none	FAIL	FAIL	FAIL	FAIL
accept	analytical	FAIL	BY ROTE	UNDERSTANDING	UNDERSTANDING
accept	design	FAIL	BY ROTE	UNDERSTANDING	UNDERSTANDING
accept	inspiration	FAIL	BY ROTE	UNDERSTANDING	UNDERSTANDING
require	none	FAIL	FAIL	FAIL	FAIL
require	analytical	FAIL	BY ROTE	UNDERSTANDING	INTERNALIZATION
require	design	FAIL	UNDERSTANDING	UNDERSTANDING	INTERNALIZATION
require	inspiration	FAIL	UNDERSTANDING	UNDERSTANDING	INTERNALIZATION

Figure 58: Complex rules of learning ability in 2D.

Some rules are trivial: if one of the attributes takes its worst value, the outcome is *«FAIL»*. The rest can be argued using the previously described logic: the person whose *«Learning Capability»* is *«details»*, would by default have *«BY ROTE»* for *«LEARNING ABILITY»*; however, a high value of *«Attention»*, namely the *«design»* and the *«inspiration»* may enhance it to *«UNDERSTANDING»*. This would arguably not the same understanding as the one resulting from the *«relations»* in *«Learning Capability»*; e.g. an inspired person may have intuitive understanding of a cognitive schema based on her/his schemata from another discipline. Using a similar argument, it can be said, that for the *«integrate»* value of *«Learning Capability»* the *«LEARNING ABILITY»* may be degraded by the lack of interest (*«accept»* value of *«Learning Willingness»*). One may also argue that there should be more nuances of «INTERNALIZATION» according to the different levels of attention; e.g. inspired internalization may involve creation of new knowledge/ideas/hypotheses, and the analytical internalization will not have such outcome. This is true but to keep the knowledge base fairly simple some shades were omitted. If the knowledge base is customized for a particular organization, more shades can be added if there is a requirement for this.

The primary purpose of the knowledge bases introduced in this chapter was to facilitate the refinement of the ideas/hypotheses by comparing the models to the observations and thought experiments during the iterative process of modelling. Nevertheless, the knowledge base of learning ability can also be used, after customization, to evaluate potential learners regarding a particular piece of new knowledge; the evaluation can be useful e.g. for choosing a person, who attends a course, or to adjust the delivery of new knowledge to particular learners.

Apart from using it in the Doctus software, the knowledge base can also be exported in various forms, which allow the user to get evaluation of learners but not to modify the knowledge base. An example of this is shown on Figure 59, it is the MLA as exported from Doctus as an html page with on-page reasoning. This type of use is often found convenient if a large number of evaluations are to be done or when there are users involved with no knowledge of Doctus. It is essential that everybody understands the attributes and their values in the same way, even if there may be users who did not go through the process of building the knowledge base, so it is useful to create a table of descriptions such as the one in Appendix 5.
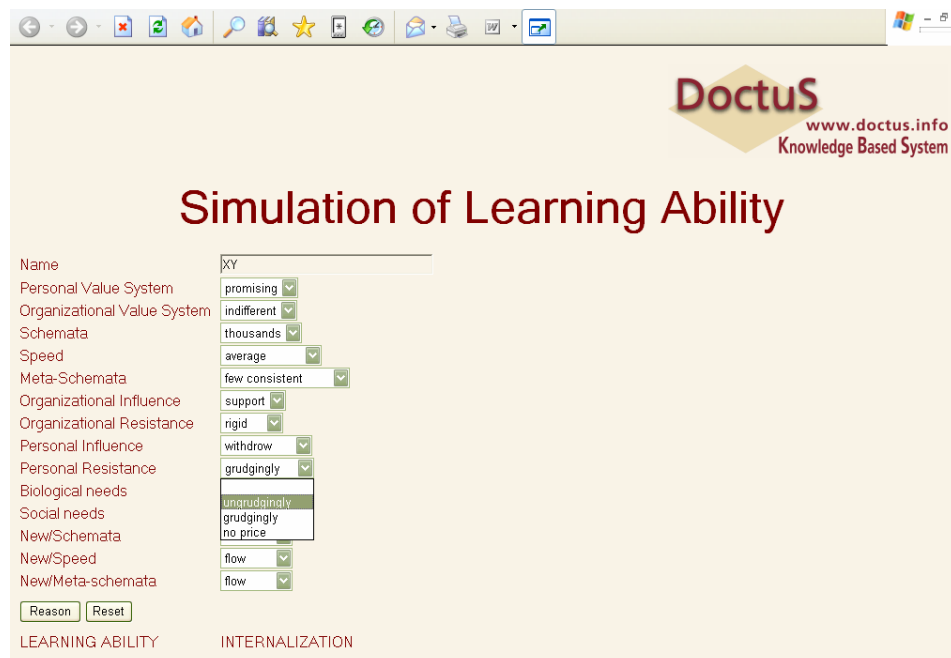

Figure 59: Knowledge base of learning ability exported – on-page reasoning.

8. Conclusions

"In conclusion, I am unwilling here to say anything very specific of the progress which I expect to make for the future in the sciences, or to bind myself to the public by any promise which I am not certain of being able to fulfil; but this only will I say, that I have resolved to devote my time I may still have to live to no other occupation than that of endeavouring to acquire some knowledge of Nature…"

Descartes[1]

The present inquiry into the process of personal knowledge increase resulted in three component models that were then integrated into a single one. The scientific problem that was tackled was properly formulated after much preparation only in the last section of Chapter 5. The long preparation was due to the precaution taken not to violate some problem-boundaries if it can be helped, i.e. to claim validity for the model only in domain where it is really valid. The problem, finally stated in positive form in Chapter 5, was:

"Which factors determine the increase of personal knowledge of a member of an organization, which occurs by absorbing new knowledge; and how these factors work?"

The present chapter is going to give an overview of the research findings and the ideas that were raised during the process, as well as suggesting new ways forward. The focus is on the lessons learned, on the contribution, and on ideas for future investigations. The style of this chapter is very different from the previous parts of the dissertation. Up till now it was important trying to justify what was said; here much is subjective, based on accumulated experience and on endless hours of reading and thinking. This does not mean that what is said here is less valuable or less important, only that it is in early stage of development.

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[1] *Descartes (1637, p. 61)*

What is to be said in this chapter is divided into three overlapping sections: the first focuses on the main findings, giving a large-scale overview and examining the possibilities of generalization; the second enumerating the ancillary findings; and the last focusing on future research directions. These areas necessarily overlap, as a result may also be a problem for future investigation.

8.1. Main Findings

The aim of this section is to give a high-level synopsis of the main results of this dissertation (instead of repeating the details) trying estimate the importance of the achieved results. What is described here is the contribution of the present research from two aspects: (1) what is the contribution to knowledge, i.e. what it adds to available knowledge – this was called the growth of knowledge in Section 4.2.1; (2) how can the result be applied, i.e. the potential use of the results outside science. These two aspects will be addressed from the viewpoint of the particular models later in this section, but first they are addressed here from the viewpoint of the whole research.

Contribution to knowledge: The aim of the research was to provide better understanding of the process of knowledge increase; this was achieved by the explanatory feature of the models. The examined factors relating to the ability of the individual to learn a particular piece of new knowledge have not previously been investigated. The resulting model is not a dynamic one (i.e. it does not model the process itself) but the arguments behind the model considered many dynamic features, so it may arguably be a step towards a dynamic description. The model, also explains some previously recognized phenomena, e.g. why it is better to have few consistent meta-schemata when acquiring new knowledge, or why the learner at the high-end of advanced knowledge learns significantly more slowly than the beginner.

However, being optimistic, one may envisage a forceful dynamic knowledge model, or even a dynamic theory of knowledge, which could grow out from the presented models. Of course, the presented models are not sufficient for that but they may be one of the roots; another one can be the evolving model of knowledge, which

is briefly described at the very end of the Conclusions. Of course, considerable work is still to be done – human knowledge is a huge area.

Perspective applications: Apart from providing explanations, the models can also be used in real-life situations to evaluate potential learners, i.e. the MLA brings together the component models into a single benchmark describing the learning ability of an individual for a particular piece of new knowledge. The evaluation of the potential learners is the most obvious application, and having a single benchmark for it makes it easy to use. This can be done, to lesser extent, using the graphical presentations (in particular the 'cube'), and, more conveniently and forcefully, using the designed knowledge bases (after having it customized to reflect the organization). This may be useful for choosing which person to acquire a particular piece of new knowledge (single cognitive schema) and for adapting the delivery of new knowledge to particular people. To do this, we do not need to design a new knowledge base every time, we should only fill in the 'case features', i.e. describe the new knowledge and the potential learners according to the input attributes of the knowledge base; and then apply the rules by running the rule-based inference of Doctus. The output is the learning ability of the particular learner regarding a particular piece of new knowledge.

The second, still fairly obvious, application is that if one goes through the process of building and customizing the knowledge base in an organization the participants will learn a lot about learning (this makes sense if the organization values this kind of knowledge of its members). This may be useful for them as learners or as educators or as course managers. The trickiest application still remains: evaluation of experts. When working as consultants for various organizations, we usually used Doctus to build a knowledge base of the experts' knowledge. Sometimes we had to realize that the so called experts are not experts (once we even found beginners in such position), which is an inconvenient situation as an expert system can only be built from the expert level knowledge (a beginner-level knowledge base is useless, see Section 4.1.8). We began to recognize potential patterns suggesting expertise but the customer, usually the CEO or someone at the top, had to take our word for it, we could not provide

sound evidence. Now, the logic from the modelling process can be reversed and the knowledge level of the participating 'experts' can be estimated.[1]

These were the contributions to knowledge and application of the overall research and thus of the MLA. The limitation of the most limited component sets the limit to the final model as well; so the MLA probably cannot be extended beyond knowledge increase (including the other types of knowledge increase apart from learning, as we shall see in the forthcoming paragraphs). The possibility of extension needs further research. In the remaining part of this section the contribution, the limitations, and the ideas for extensibility are described for the component models.

For the MLW[2], personal and organizational value systems and their interaction were used to get to the judgment: 'is the person willing to learn the new knowledge or not?' The concepts[3] (attributes and values) were adopted from the literature (see Section 4.2.9) and the rules[4] were formulated on the basis of observations about learning; nevertheless, they appear to be more general than the observational situations. The first attempt re extension could be to have a look if the model is valid for other forms of knowledge increase apart from learning, i.e. for experiencing events, for practising, and for inner experience (see Subchapter 4.3). A guess is that it may be valid for the first two, and un-decidable for the third one (i.e. it may be inaccessible for a scientific research). This extension probably does not need modification of the introduced concepts (attributes and values), as the other forms of knowledge increase can be described using the same terminology. The second step could be to try do extend the MLW to other kinds of changes besides the knowledge increase; namely to willingness for other kinds of novelties, such as introducing a new member of organization or launching a new products.

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[1] *This means that the above mentioned patterns that we began to recognize could be reengineered in a formalized way.*

[2] *The MLW was published as a conference paper. (Dörfler, 2003)*

[3] *The 'concepts' in all models refer to the factors and their grades, that is attributes and their values as they are called in Doctus.*

[4] *The interrelations of the concepts are described in Doctus by rules – and this is how they are referred to throughout this section.*

The MLC[1] describes how the existing personal knowledge affects learning. The concepts (attributes and their values) were deduced on the basis of systemic description of knowledge, also making use of the inherent nature of the adopted mathematical symbolism.[2] The rules were determined on the basis of observation. The supposed validity is the learning, but a personal episode initiated thinking about the possibility of remarkable extension:

> *I gave a presentation about the findings of the dissertation on a departmental seminar, after which I had a chat with Val Belton and Bob van der Meer. Bob said that the function of learning capability seemed very powerful. We discussed this from several aspects, and this made me think about the generalisability. When I examined what was actually used to reveal the qualitative inferences about the model, I realized that it may really be much more general: the only knowledge-specific feature that remained in the model is that the meta-schemata were formed by enlightenment, so in zero time. So how general this model may be?*

The consideration that the meta-schemata form and reform by enlightenment means that the structural changes are considered to be transient. This means that it is possible (the previous rationale is not satisfactory as it was only concerned with what *was* considered, and a proper argument should also examine what *was not* considered; which means that the whole process of modelling should be repeated from scratch, using a different starting point) that the model can be used for any kind of system in which the structural changes are transitory or where we are not interested in the process of transition from the old structure to a new one. This can be the case e.g. with a business process reengineering (BPR), resulting in a different organizational structure, of a supplier for a company, if it happens in a short time. Such substantial extension is, of course, only a possibility for now and its examination requires substantial further research.

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[1] *The MLC was published as a conference paper. ([Dörfler, 2004a](#))*

[2] *For the MLC the concepts were acquired from Zoltán Baracskai, but they were also discovered by pure deduction – a day later.*

The MA[1] describes under which (cognitive and motivational) conditions the person is able to pay attention to the new knowledge; in this model it is supposed that the person is willing to pay attention – as provided by the MLW. The strength of this model is that there are diverse areas pulled together that are usually only investigated separately; here the attributes and values, as well as the rules are formulated by restructuring and integrating pieces from the various background disciplines. This diversity of background is also a source of its weakness, i.e. while restructuring Maslow's model, it was realized that the social level should be described using several dimensions[2]: money, power, knowledge (usually called technology), and belongingness (often called social needs). From these, only belongingness was taken into account and the knowledge was the focus, so two were omitted. This is a severe limitation of this model, i.e. it is valid only if we can assume that the differences between the potential learners are negligible along the two omitted dimensions. However, including the remaining two dimensions would require a separate doctoral research. The way in which the model is constructed does not necessarily have to be different; probably only the two dimensions should be added. This is possible if we can describe the two additional dimensions similarly to the considered ones – but only if we try will we find out whether this is true. The MA, similarly to the MLW, could probably be extended to include other kinds of knowledge increase apart from learning, i.e. experiencing events, practising, and inner experience (see Subchapter 4.3). This, however, similarly to the MLW, needs further research.

These were the contributions of the main findings that were recognized so far. Apart from main results, there were some supplementary results achieved as well during the research; these are briefly described in the next section.

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[1] *The MA was published as a conference paper. ([Dörfler, 2004b](#))*

[2] *These dimensions are usually used by sociologists and, sometimes, by economists to describe the relation of the individual to the society/organization and other social phenomena. These are e.g. the factors of the PEST (Political, Economic, Social, Technological) analysis.*

8.2. Ancillary Findings

This section gives an overview of those results that are included elsewhere in the dissertation but do not fall into the mainstream of this research. These were achieved at some stage of the research process and they influenced the main results or the process itself for achieving them. New problems that were identified but not solved during this research are included in the next section.

The critical review of literature contains two kinds of added value: (1) there are some new ideas added to what can be found in the literature, based on observations and/or thinking further the introduced models/conceptions from the literature; (2) there are several syntheses done putting together different conceptions that were not considered together previously. Ancillary results of the first type are:

- Recognizing the difference between knowledge (as something one possesses) and knowing (an act involving knowledge) in Section 4.1.5 enabled significantly better understanding of knowledge (a neat metaphor is the difference between potential and kinetic energy); e.g. understanding that the apparent contradiction of Polányi's (tacit and explicit knowing) and Baracskai's (tacit and explicit knowledge) model can easily be resolved if we distinguish between knowledge and knowing. This idea will probably be of good use if trying to get to the dynamic theory of knowledge. (cf. previous section)

- Knowledge of 'why' and 'what' are added to Ryle's original model of 'that' and 'how'. (See Section 4.1.6) Later it was recognized that Gurteen already defined the 'why'-type, so only the 'what' knowledge is an original contribution. Apart from providing better understanding of the nature of knowledge, this is one of the beginnings[1] to examine the knowledge of leader more closely (as the knowledge of leader is 'what' knowledge); this is now an ongoing line of research.

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[1] *Another of the beginnings is the evolving knowledge model, which is briefly introduced at the very end of the Conclusions.*

- There were two simple exercises introduced in Section 3.5, which provide better explanations for the conception of attention; i.e. it explains the parallel processing, which is often considered to be a result of divided attention from a cognitive aspect. The exercises suggest that the focal attention is not divided but two simple tasks are merged into a single one, if they are to be performed simultaneously. This result is, again, not sufficient for a stand-alone-publication; it could be the first step of examining how we are creating meta-schemata by merging two simple ones if we are to use the two at the same time. Similarly to several previous findings, the two exercises may also find their role in the process of getting to the dynamic theory of knowledge.

- The conception of automated fuzzy-clustering for knowledge-based system using symbolic logic[1] (particularly for Doctus) was developed in the early stage of research when it was assumed that it may play part in the main result. However, the research took another direction. Nevertheless, it is a valid result in itself. Its significance is in potential business applications, i.e. frequently there is a need to combine inputs from experts and from databases/data warehouses, when building a knowledge base. This is usually a difficult and demanding process: to handle the existing clustering algorithms the expert would need expertise in statistics as well apart from her/his domain of expertise (which she/he usually does not have); and the communication between the statistics expert and the domain experts is rarely smooth (they do not have a common language). Thus, this conception of fuzzy clustering is aimed to provide understandable results to the experts with no statistical background, without loosing relevant information provided by clustering. To have a real-life application, the conception needs to be converted into a computer program.

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[1] *Baracskai-Dörfler (2003).*

There are four examples of the second type of contribution:

- In Section 3.1 two approaches to rationality, namely Simon's conception of bounded and Baracskai's conception of intuitive rationality, were examined and integrated into a single conception – it was named the *integrated rationality*.[1]

- In Section 3.4 several models of cognition were put together into a single picture, which is here called the *"generalized model of cognition"*. This model contains no new elements; its purpose is to integrate several already known models into a single entity. (Figure 13) The contribution here is that these models were never put together previously, probably because they seem to be too big to fit into a single picture. But exactly having all these models in a single picture makes it easier to grasp how the cognitive processes work. This is obviously insufficient for any kind of publication but it may help in teaching about knowledge – it is a reasonably explainable picture.

- Levels of process complexities were described in Section 3.2 similar to the levels of system complexities of Boulding. There are no new findings added to these descriptions, only the prior knowledge was rearranged to represent the different complexity levels of processes as a hierarchy. The significance of this finding is that it directs the attention, i.e. processes at different levels of complexity require different (mathematical or other) tools; this often causes trouble especially for those coming to systems from a neighbouring discipline (e.g. they often think that the chaotic processes are more complex than the heuristic ones, thus they use inappropriate tools, and then they struggle with modelling).

- The knowledge typologies introduced in Chapter 4 were examined from the viewpoint of knowledge and from the viewpoint of knowledge increase, and based on these analyses their interrelations were

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[1] *Dörfler (2005).*

found and the different typologies were synthesized. (See Table 2 in Subchapter 4.3) The significance of this result is that by synthesizing the various knowledge typologies the interrelations between these typologies are made clear, which in turn provides better understanding of knowledge altogether.

This section described in the ancillary results, i.e. results that were achieved during this research but that do not belong to its mainstream and thus to main findings. The next section focuses on problems that were identified but not solved during the investigation.

8.3. Future Directions

Besides results, as in any process of scientific problem solving, in this research several new problem areas were identified. As can be seen in the previous two sections, some of the results suggest possible research directions. The identified new problem areas also suggest possible research directions; some of them even more than one direction. The new problems identified during the present research are briefly described in this section. Sometimes during the research, more or less connected to it, some underlying 'truths' were recognized; using the language of the dissertation we could say that some complex meta-schemata were formed. These are possibilities for now, areas for exploration and tentative hypotheses; some may develop into scientific results in the future.

The most obvious problem was already described in the first section of Conclusions. This is about the MA, in which the description of the social level should be refined by including the dimensions of money and power. The ideas about the extensions/generalizations of the four models (MLW, MLC, MA, MLA) were also introduced in the same section. Still in the same section, there was also an idea about a further addition to the main result that is actually not a scientific problem but a software development problem; nevertheless, it is an exciting work that could result in useful application. The idea was that a module could be developed, (as it was explained in Section 8.1), for knowledge-based systems (more specifically for Doctus

KBS Shell) that could provide automatic evaluation of the experts. These ideas were all explained in detail in Section 8.1, this was only a short reminder that they belong here too.

Once the research had been finished and the dissertation partly written, it became clear that there should be one more 'leg' of MLA, namely talent. This idea is in its early stage; the basis of it is the realization, that there is another cognitive component apart from the existing knowledge and the cognitive factor of attention (these two were modelled in this research, tacitly assuming that only talented people are evaluated). The adopted mathematical symbolism was the source of this realization: Functions cannot only be derived by time but also by the dimensional variables. If we want to draw a picture of knowledge, what would be the dimensions? Probably there are other possibilities, but I can imagine personal knowledge as a hyper-surface in a coordinate system, where the dimensions are the disciplines. The greater the knowledge of the person in a particular discipline, the higher value the surface meets the corresponding coordinate-axis. As the knowledge increases, the surface grows; when the person learns something in a particular discipline, the surface extends along the corresponding dimension. The talent is not bonded to a single discipline, it can rather be imagined as a combination of disciplines; this combination assigns a line on the surface, the talent would be the gradient of this line.

When working on value systems and on motivation, it was recognized that we actually know little about what motivates our value systems or how. This is probably more than a problem – this could be a complete research program in Lakatos' sense.

There is another problem identified, which also does not belong to domain of science. It belongs to the philosophy of science. By introducing the conception of paradigms, Kuhn also created the meta-paradigm of paradigmatic sciences. Since that time many things have changed. One of these is that, similarly to the social level of Maslow in MA, the description is not complete without including the dimensions of money and power; although it must be acknowledged that in Kuhn's time it might had been reasonable to neglect these (i.e. the roles of power and money might had been of lesser significance in science). In addition to this, Kuhn maintained the metaphor of building with regards the growth of scientific knowledge, although he

noted that besides construction there is also deconstruction and sometimes we may even leave the building-place. Probably the time has arrived to give up the building metaphor and to replace it with the metaphor of the *'web of metaphors'*, as suggested by Capra. This would mean abandoning the idea of strict definitions completely and allowing any starting point for scientists, which probably reflects our turbulent world more appropriately. This is, at the moment, a strange idea only but it would worth to try initiating debates about it amongst today's philosophers of science.

Some insights that were born during this research are the following:[1] (1) For the apprentice of science, the master (see master-apprentice relationship at various places throughout Chapter 4) must be from the same paradigm but may be from another discipline; and the guru[2] must be from the same discipline but may be from a different paradigm.[3] (2) There is a kind of symmetry in levels of system complexity, namely, in very small systems, an individual system is more complex than the demographic system (e.g. subatomic particles); while in large systems the demographic system is more complex than an individual one. (3) We could not describe processes appropriately because we assumed that a process is the activization of relations between the elements of a system; processes are actually activizations of structures. These three, insights are all possible directions for new research.

To conclude this dissertation, let's consider an interesting new idea, which was conceived when examining knowledge from various perspectives. It had two other sources in addition: the idea of the *"one-dimensional man"* from Marcuse (1964) and the ancient *"Tabula Smaragdina"* by Hermes Trismegistos. This idea is the basis of new research, which has already started to bear fruits. The first results are in-

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[1] *These are in their very early forms; they can already be formulated but not very well argued yet. Although they are stated in positive form, they are far from being certain.*

[2] *Here the gurus are interpreted as the greatest minds in a discipline; they form the paradigms. There are usually only very few gurus in a discipline; typically one per paradigm, rarely two.*

[3] *Prior to this, both Baracskai and I formulated independently of each other half of this meta-schema, namely that the master may be from a different discipline but the guru must not.*

cluded in our last book.[1] ([Baracskai-Velencei-Dörfler, 2005](#)) The idea is that knowledge can be described by the number of 'dots' one is able to see. Seeing one 'dot' is dimensionless (0-D) knowledge, a person with 0-D knowledge is only able to learn facts (or doctrines presented as facts). Two dots may be connected by an arrow; this is the one-dimensional (1-D) knowledge. A person with (1D) knowledge can see connections, causal relations, «if… then» relations, etc. It can be expected that the next level should be called two-dimensional (2-D) knowledge and be described by three dots. If one sees three dots the simple relations from the previous level will prove unhelpful for providing satisfactory explanation. Thus we may describe this knowledge level with three sets in intersection. This does not mean, of course, that on this level the knower cannot handle e.g. causal relations (any two from the three dots may be connected by an arrow); this means that here we can have a richer picture of less rigid relations, such as intersections. Four dots establish three dimensions, the 3-D knowledge is less known, it is e.g. when a (grand)master uses a parable to enlighten her/his disciple about a complex piece of knowledge. Not many of us can draw in more than three dimensions, or even imagine it. The fifth dot does not indicate a new dimension, it brings the four to equilibrium; it can be imagined as being in the middle of a tetrahedron. It has already been found out that the dimensions of thinking clearly correspond to the levels of knowledge described by the number of cognitive schemata. Its strength in comparison to the 'old' model of knowledge levels is in providing easy understanding of qualitative differences. A lot of further research is still to be done on this model, but, as it was indicated in Section 8.1, it may well be a major step towards dynamic theory knowledge.

> *An eager young man once came to the Zen Master wanting to become his disciple. The Master offered him a cup of tea. He started to pour the tea into the cup of the new disciple and continued pouring even when it started to overflow. The new disciple tried to stop him: "What are you doing? You can't pour in any more! The cup is overflowing!" The Master gently answered: "Your mind is like this teacup. It is full. I cannot teach you unless you first empty it."*
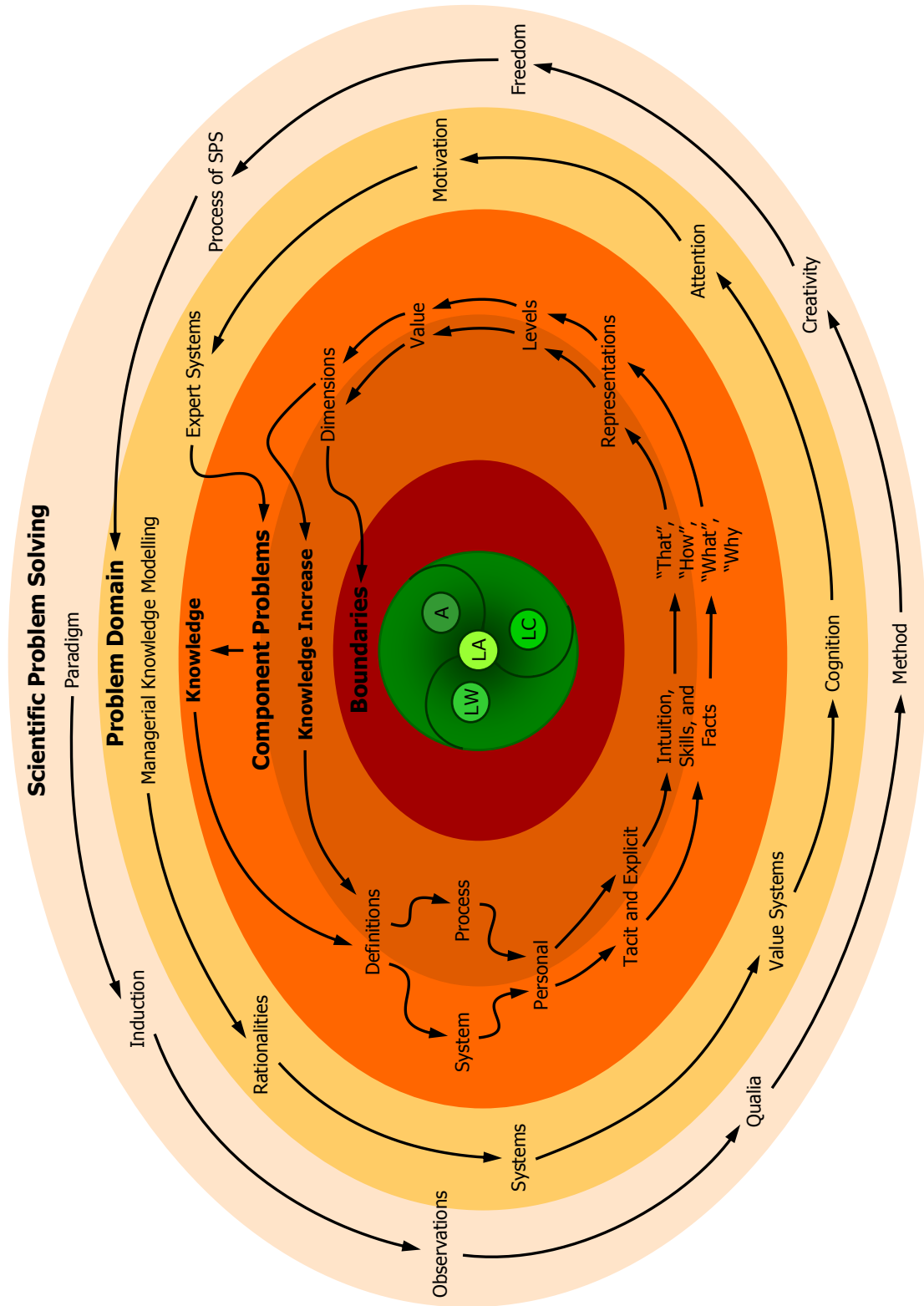>
> *Zen story*

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[1] *The following description is based on the first results achieved in discussion between Baracskai and myself.*

9. Appendices

Appendix 1   Concepts Used in the Dissertation
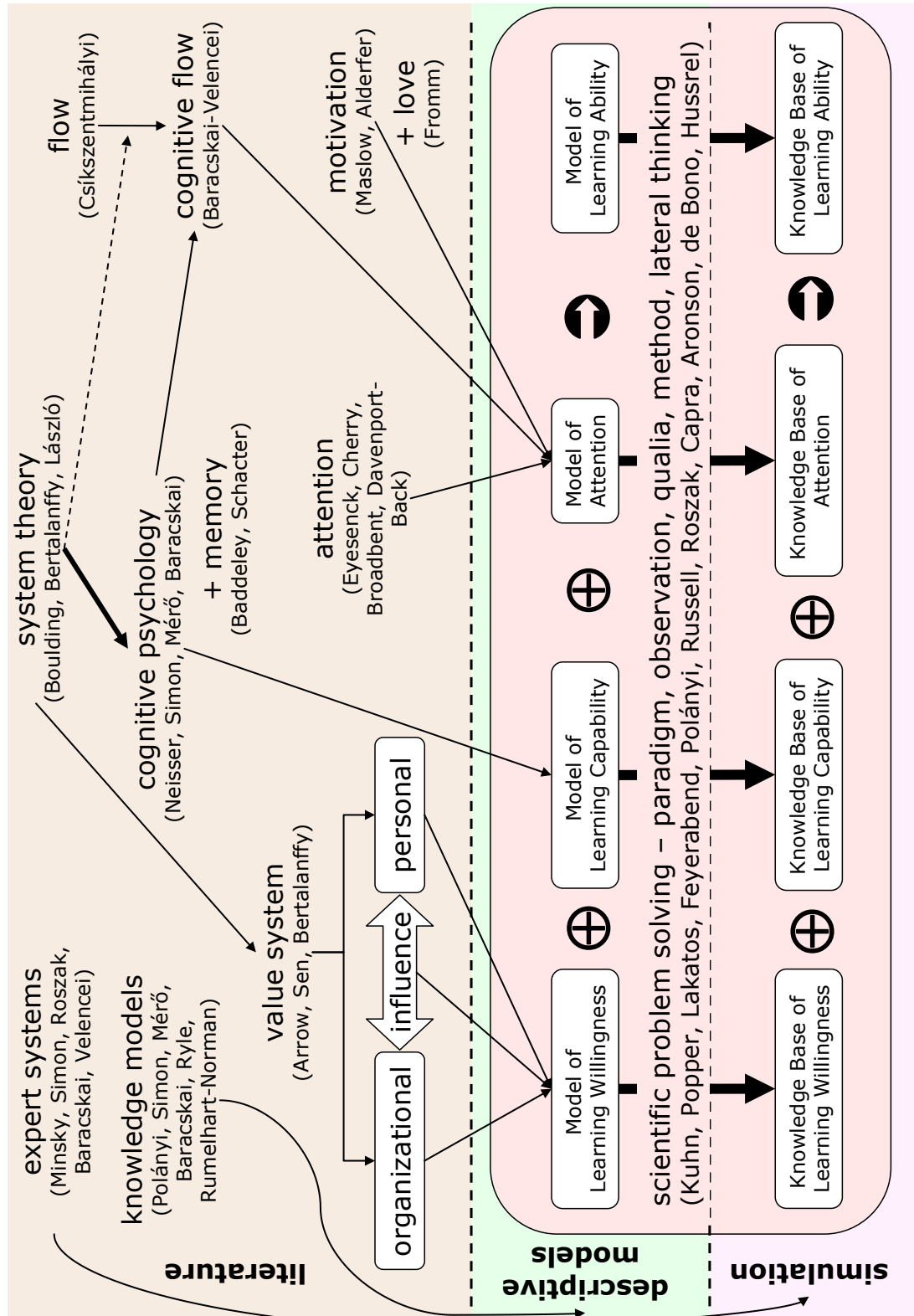
Appendix 2   The Line of Discussion

LW – Learning Willingness, LC – Learning Capability, A – Attention, LA – Learning Ability

Appendix 3   Case-Based Reasoning

There are two basic conceptions of obtaining rules in symbolic CBR:[1]

(1) The **AQ algorithm** ([Clark-Niblett, 1987](#)) smoothes an arbitrary rule until it becomes acceptable. First it classifies the cases according to the benchmark (outcome) values; then it takes one case from the first class, which is the core-example, and one from the second class, which is the counter-example. Afterwards it finds the most general rule (by expanding the rule domain) that covers the core-example, but not the counter-example. This is repeated for all the counter-examples (all cases of the rest of the classes); then it compares each core-example (each case in the first class) to the rule and the covered core-examples are removed from the case base. By doing so, a rule is constructed that covers plenty of core-examples, but not a single counter-example. These steps are repeated for the rest of the core-examples until all of the cases from the first class are used up. Then the whole process is repeated for the rest of the classes. Outcome is usually portrayed in the form of rule-list.

(2) The **ID3 algorithm** ([Quinlan, 1986](#)), on contrary to the previous, searches for an acceptable rule. Let's presume that all cases form a disordered set, where the order is defined as homogeneity by benchmark values (cases in one subset have the same benchmark value). The attribute is searched, which contributes the most to the order. The attributes are taken one-by-one, forming subsets according to their values. Their strength in contributing to order is measured by an entropy-gain (informativity) calculating algorithm (Appendix 4). The most informative attribute is chosen and the first level subsets are formed according to its values. These subsets are further divided using the same algorithm until all subsets are homogenous by the benchmark values. The usual form of appearance is a decision tree.

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[1] *Here only the conceptions are shown, which were used as the basis for the algorithms. Even though the original algorithms are further modified in multiple ways, mainly due to technical reasons (e.g. achieving greater speed, avoiding endless cycles), the conceptions are still valid.*

Appendix 4 Informativity Calculation

Determining *informativity (I_b)* of attribute *b*:

1. Let *C* be the set of cases in a node, *a* the benchmark, *$a_1…a_n$* its values, and *$w_{a1}…w_{an}$* ($\sum_{i=1}^{n} w_{ai} = 1$) their rates in set *C*. The entropy of benchmark in set *C* is: $E_C = -\sum_{i=1}^{n} w_{ai} \log_n w_{ai}$.

2. Let *$b_1…b_m$* be the values of attribute *b*, *β* is a set of them. Disjoint *β* into not empty subsets *$β_1…β_p$*, where $\bigcup_{j=1}^{p} \beta_j = \beta$.

3. Disjoint *C* into subsets *$C_1…C_p$* being attribute *b* of all elements of *C_j* in *$β_j$* for each *j*. Let *w_j* be the weight of *C_j* in *C*, where $\sum_{j=1}^{p} w_j = 1$.

4. Then informativity is the entropy gain of disjoining *β* into *$β_1…β_p$:* $I_b = E_C - \sum_{j=1}^{p} w_j E_{Cj}$.

5. The output of the computing is informativity of the optimal selection: $I_{b\max} = \max_k (I_{bk})$, where *k* indicates the possible disjoints of *β*.

Density of it is: $D_b = \dfrac{w_C I_{b\max}}{E_C}$, where *w_C* is the number of elements in set *C*.

Appendix 5 Value descriptions

Table 5: Description of values in MLA.

Attribute	Value	Description
LEARNING ABILITY	FAIL	The person does not learn the new knowledge.
	BY ROTE	The person learns the new knowledge by rote, with no understanding.
	UNDERSTANDING	The person understands the new knowledge but does not internalize it yet.
	INTERNALIZATION	The person learns the new knowledge at the highest level: internalizes it.
Learning Willingness	reluctant	The person is reluctant towards the new knowledge.
	accept	The person accepts the new knowledge.
	require	The person requires the new knowledge.

Attribute	Value	Description
Personal Value System	ominous	The person considers the new knowledge to be ominous.
	neutral	The person is neutral towards the new knowledge.
	promising	The person considers the new knowledge to be promising.
Organizational Value System	harmful	The organization considers the new knowledge to be harmful.
	indifferent	The organization considers that the new knowledge has no value for it.
	useful	The organization considers the new knowledge to be valuable.
Influencing	organizational	The judgment of the organizational value system dominates the judgment of the personal.
	conflict	Neither the person nor the organization is willing to change her/his judgment in rate, which would be enough to get to a stable position - usually result in change in the relation between the person and the organization.
	in between	Both the person and the organization have made concession, they both modified their judgments and have agreed somewhere between their previous judgments.
	personal	The person has succeeded in convincing the organization, the judgment of her/his value system has become accepted.
Organizational Influence	forbid	The organization forbids to the person the acquisition of the new knowledge.
	tolerate	The organization tolerates the acquisition of the new knowledge.
	support	The organization encourages the person to acquire the new knowledge.
Organizational Resistance	rigid	The organization rigidly resists reconsidering its judgement on the new knowledge.
	flexible	The organization is flexible in reconsidering its judgment on the new knowledge.
Personal Influence	withdraw	The person remains silent, does not attempt to convince the organization.
	set example	The person tries to make the organization to reconsider its judgement on the new knowledge.
	raise voice	The person wants to enforce her/his opinion upon the organization.
Personal Resistance	ungrudgingly	The person changes her/his judgment on the new knowledge ungrudgingly.
	grudgingly	The person reconsiders her/his judgment but grudgingly.
	no price	There is no price for the person to reconsider her/his judgment on the new knowledge.
Learning Capability	nothing	The person is not capable of learning the new knowledge.
	details	The person is capable of learning details without seeing relations between these details.
	relations	The person is capable of understanding the relations between the elements of the new knowledge.
	integrate	The person is capable of the highest level of acquiring the particular new knowledge.
Schemata	tens	The person has few tens of cognitive schemata that can be related to the new knowledge.
	hundreds	The person has few hundreds of cognitive schemata that can be related to the new knowledge.
	thousands	The person has few thousands of cognitive schemata that can be related to the new knowledge.
Speed	below average	The person changes the relations between her/his cognitive schemata slower than the average.
	average	The person changes the relations between her/his cognitive schemata at average speed.
	above average	The person changes the relations between her/his cognitive schemata faster than the average.

Attribute	Value	Description
Meta-schemata	many contradictory	The person has many meta-schemata that contradict to the new knowledge; there are no consistent meta-schemata, so no structure to fit in.
	few contradictory	The person has only few meta-schemata that contradict to the new knowledge; there are no consistent meta-schemata, so no structure to fit in.
	many consistent	The person has many meta-schemata that are consistent with the new knowledge, and thus (too) many structures that could build-in the new knowledge.
	few consistent	The person has only few meta-schemata that are consistent with the new knowledge, and thus few structures that could build-in the new knowledge.
Attention	none	The person cannot pay any attention to the new knowledge.
	analytical	At this level of attention the person can analyze the new knowledge, understanding the relations within it.
	design	At this level of attention the person can relate the new knowledge to her/his existing knowledge and fuse them.
	inspiration	At this highest level of attention the person usually fuses the new knowledge with her/his existing knowledge in manner that the resulting increased knowledge jumps over some steps and finds something new. This is when we say: she/he learned more than she/he was taught.
Cognitive factor	anxiety	From cognitive point of view the person is unable to pay any attention in state of anxiety.
	boredom	The person is bored with the delivery of the new knowledge; pays limited attention.
	flow	In state of flow the person can pay sharp attention.
New/Schemata	anxiety	The person is anxious as she/he does not have schemata to which the new knowledge could be connected.
	boredom	The person has substantial existing knowledge in the area of the new knowledge; actually she/he already knows most of it and thus she/he is bored.
	flow	The person has exactly that level of existing knowledge in the area of the new knowledge that it is interesting to her/him; she/he can pay sharp attention.
New/Speed	anxiety	The delivery of the new knowledge is too fast, the person is anxious, she/he can pay little attention, if any.
	boredom	The delivery of the new knowledge is too slow, the person is bored, she/he pays attention only occasionally.
	flow	The new knowledge is delivered exactly at the appropriate speed, the attention is sharp.
New/Meta-schemata	anxiety	There are too many structures that could build-in the new knowledge; the person cannot catch up.
	boredom	The person has only structures that contradict to the new knowledge, no consistent structures whatsoever. She/he usually thinks that the new knowledge is stupidity.
	flow	Several structures can build-in the new knowledge; everything makes sense.
Biological needs	unsatisfied	The person has much more important things to think about. Any attention is out question.
	satisfied	There are no distracting needs from biological point of view preventing the person to be able to pay attention.
Social needs	none	The social needs of the person are not at all satisfied, she/he cannot pay any attention to the new knowledge.
	philos	The person has friends, which enables her/him to be capable of analytical attention – if the other factors are OK.
	eros	The person is satisfied with her/his love-life, both with friends and her/his partner.
	agape	From social (emotional) viewpoint the person is consumed with what she/he is doing, can be inspired in learning.

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Glossary of Terms and Acronyms

AI – Artificial Intelligence

CBR – Case-Based Reasoning

BPR – Business Process Redesign/Reengineering

Decision making – A preparatory stage of the decision process, often realized by decision support teams, involves generation and evaluation of decision alternatives, and decision aspects.

Decision taking – The final act of the decision process, the judgment.

ES – Expert System

FC – Fuzzy Clustering

FL – Fuzzy Logic

GST – General System Theory

KBS – Knowledge-Based System

Knowledge increase – More general than learning, also includes inner and outer experience, and enlightenment.

Learning – A special case of knowledge increase which happens by absorbing new knowledge.

LTM – Long-Term Memory

MA – Model of Attention

MLA – Model of Learning Ability

MLC – Model of Learning Capability

MLW – Model of Learning Willingness

NN – Neural Network

Qualia (singular quale) – Subjective experience, introspectively accessible, phenomenal aspects of our mental lives.

RBR – Rule-Based Reasoning

SL – Symbolic Logic

SODA – Strategic Options Development and Analysis

SSM – Soft System Methodology

STM – Short-Term Memory (recently the term working memory is also used)

TQM – Total Quality Management

TSI – Total System Intervention

WM – Working Memory (the new name of the STM)

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