Mapping in the Educational and Training Design

Svetoslav Stoyanov

Doctoral committee

Chairman

Prof. dr. Jules Pieters

Supervisor

Prof. dr. Jef Moonen

Assistant Supervisor

Dr. Piet Kommers

Members

Prof. dr. Betty Collis
Prof. dr. Joseph Kessels
Prof. dr. Arno Libotton
Prof. dr. Jeroen van Merriënboer
Prof. dr. Wim Nijhof

CIP-GEGEVENS KONINKLIJKE BIBLIOTEEK, DEN HAAG

Stoyanov, Svetoslav

Mapping in the Educational and Training Design
Thesis University of Twente, Enschede – With refs – With summary in English and Dutch.

ISBN: 90 365 169 35

Press: Print Partners Ipskamp, Enschede

MAPPING IN THE EDUCATIONAL AND TRAINING DESIGN

DISSERTATION

to obtain

the doctor's degree at the University of Twente,

under the authority of the rector magnificus,

prof.dr. F.A. van Vught,

on account of the decision of the graduation committee,

to be publicly defended

on Friday 16 November at 16.45

by

Svetoslav Todorov Stoyanov

born on 24 July 1958

in Vratsa, Bulgaria

This dissertation has been approved by:

Prof. Dr. J. C. M. M. Moonen, supervisor.

Dr. P. A. M. Kommers, assistant supervisor

Table of contents

List of figures

List of tables

Acknowledgements

Reflecting back what happened in my life it seems to me that it has been inevitably linked to the Netherlands. I spent a big part of my childhood living together with my grand parents in a village very near to Sofia, Bulgaria. Just beside my bed on the wall there was a tapestry representing a landscape apparently not Bulgarian. I had never paid attention to it nor I had been interested to know which country this landscape was representative of. The tapestry is still there. Five years ago when I came in the Netherlands to join MSc programme of the Faculty of Educational Science and Technology at University of Twente I suddenly realised that it was typical Dutch countryside that this picture showed. Ironically being not sure whether I would get scholarship for the Master programme I was ready to sell the house together with this tapestry.

It goes to my teenage time when I became (and I am still) a great admirer of Dutch national football team. I have a big collection of everything related to Dutch football. However I have to admit that it was not the Netherlands I dreamed to visit, needless to say to live there (here).

Working in Sofia University I got opportunities to visit (after the communist regime in Bulgaria collapsed) some universities in France, England, and Belgium. I heard the names of Betty Collis and Jef Moonen many times. How could I know that I would do Ph.D research in the department whose chairman was going to be Prof. Betty Collis and my promoter would be Prof. Jef Moonen. After so many coincidences I began to believe in destiny.

It is a time to give thanks. I would like to brainstorm the names of the people to whom I am grateful for contributing directly or indirectly to my dissertation.

To the group of friends who I play football with in Hengelo for the exciting time and the opportunity to compensate some defeats in writing dissertation.

To all my colleagues from the ISM department for the good atmosphere and friendship.

To my paranimfs (assistants). Carin and Koos for the willingness to share the nervousness.

To my friends Sonia and Ivan Stanchev for the support, nice time and delicious food.

To Ivan Kurtev, who mastered to program some complicated ideas in SMILE Maker.

To Claartje, Leo and Frank for introducing me to the world of creativity.

To my colleagues and friends form Sofia University Iliana, Roumen, and Krassen I had pleasure to work with.

To Johan from TO Lab for his responsiveness to give technical help when I need it.

To Salah who prayed for me.

To Dio who always was helpful with ‘those small things’ that were so important.

I am deeply indebted to Betty who gave me confidence and courage, to Piet for the intellectual stimulation and Jef for the credit, guidance and patience.

To Mama, Neli and Slavko for being always with me.

Enschede, October, 2001

Chapter 1. Introduction

The goal of this study is to design, develop and evaluate the effectiveness of a tool for improving the educational and training design process. The tool applies a problem solving method consolidating some mental mapping approaches and some creative problem solving techniques. It supports the individual process of solving design problems. In addition to that, the tool proposes an individualized learning environment for studying this problem solving method.

The Chapter 1 introduces the theoretical and the practical context of studying the role of mapping methods and tools in improving the educational and training design process. It identifies existing tendencies and issues both in the domains of design paradigms and problem solving methodologies, and mapping approaches. Based on this research questions are formulated and the approach to answer them is shortly discussed. The chapter consists of the following sections: 1.1 Research context, 1.2 Solving design problems, 1.3 Mapping, 1.4 Research questions, and 1.5 Overview of the study. Section 1.1 Research context reports on the needs, purposes, relevance and the target group of the study. A short clarification of the term 'mapping' is given. Some references to different mapping and problem solving approaches are presented. A short description of a new method for solving design problems can be found here as well. The general research question is formulated. Section 1.2 Solving design problems shows the close conceptual connection between problem solving and design. Educational design paradigms are discussed and some tendencies common to the design methodologies of education, engineering, and business management are identified. This section concludes with a summary of the educational and training design issues that should be addressed if the goal is improvement of the process of solving design problems.

The purpose of the Section 1.3 Mapping is to say how and why mapping techniques contribute to solving design problems and what the issues are that should be encountered. The term 'mapping' is introduced in two planes: firstly, as an abstraction, or a general category for identifying the commonalties of the existing mapping approaches; secondly, as a method to facilitate people when confronted with ill-structured design situations. Short descriptions of different mapping approaches are given. This section also focuses attention on some of the problems of using concept mapping for solving educational design problems.

Section 1.4 Research questions formulate a set of research questions based on the analysis accomplished in section 1.2 Solving design problems and Section 1.3 Mapping. The research questions are operationalisations of the problem statement in Section 1.1 Research context.

The last section of this chapter prepares the reader as to what he or she should expect to see in the following chapters.

1.1 Research context

This section describes the goal of the study, the motives to be undertaken, the theoretical and practical background of the research, and the target group. An initial description of the new method for solving design problems developed in the framework of this research is given. The section includes the sub-sections 1.1.1 Goal, relevance and target group of the study; 1.1.2 Theoretical foundations; and 1.1.3 Preliminary research in the current project.

1.1.1 Goal, relevance and target group of the study

The goal of this study is to provide a theoretical framework and empirical evidence for the effectiveness, efficiency and attractiveness of a software tool applying a new method for problem solving in ill-structured educational and training design situations. The method synthesizes different mapping techniques and capitalizes on the traditions of some problem solving methodologies. It is intended to support students in the Faculty of Educational Science and Technology at University of Twente to design adequate, feasible and original design solutions for complex situations in the domain of education and training. In addition, the software tool offers a learning approach for studying the method for solving educational and training problems. Studying and applying the method are closely related. Learning is a part of the application of the method and the application is a part of the learning of the method. In order to apply the method has to be learned. From another perspective, the application of the method is seen as the last step of learning. The software programme is called SMILE Maker. It is a Web-based tool developed for the purposes of this study. SMILE stands for Solution, Mapping Interactive, Learning, and Environment. It provides an interactive learning environment for studying a problem solving method based on mental mapping and creative problem solving principles, methodologies and techniques. For clarity throughout the study the method will be called ‘SMILE problem solving method’ (‘solution’ and ‘mapping’ in the acronym of SMILE). The interactive learning environment (‘interactive, ‘learning ‘ and ‘environment’ in the acronym of SMILE) will be called the ‘SMILE Maker Tool’.

The Faculty of Educational Science and Technology was established with the mission of preparing students to solve different educational and training problems in the field of educational management, curriculum development, instructional design, and the application of advanced technologies for educational and training purposes. The educational philosophy of the Faculty can be defined as a problem-based learning. Students learn by solving authentic, real life problems, reflecting on the process and results of their experiences. Different design methodologies for educational problem solving have been developed to support design activities (Collis & de Boer, 1999; Kessels, 1999; Kommers, 2000; Moonen, 1999, 2000, 2001; Visscher-Voerman, Gustafson & Plomp, 1999). Section 1.3 Problem solving design and 1.4 Research issues in educational and training design provide more detail about these approaches, issues and tendencies in the domain of educational and training design.

The project also has the aim of contributing to the efforts of the researchers and instructors in the Faculty of Educational Science and Technology in their attempts to increase the effectiveness and efficiency of the educational and training design process. This can occur by providing a method and an interactive learning environment that will help students to improve their problem solving performance in open-ended design situations. The method combining different mapping approaches and problem solving techniques should support students to analyse a design situation, collect needed information, generate solutions, select the most appropriate one(s) and put it into practice.

As a part of the research program *Interactive Learning Environments* of the Department of Educational Instrumentation, the study attempts to demonstrate the instrumental value of a software tool that supports educational and training design. The meaning of 'instrumental' is twofold. Firstly, the study shows the benefits of the tool based on an advanced technology. It will discuss the design methodology, functionality and the interface of the SMILE. Secondly, the study promotes the instrumental knowledge (background information, procedures, examples, and techniques) for solving design problems.

The target group of this study are students who have as a learning task to design a product for educational or training purposes. However the research has an ambition be generalizable beyond groups of students. The educational philosophy of the Faculty of Educational Science and Technology is to involve students in real design tasks in order to reduce the skills gap and the discomfort they may experience during their initiation to the profession of educational designer. Becoming professional educational and training designers is the most typical occupational goal of the students. The SMILE problem solving method might also be beneficial for the broader target group of educational and training designers.

The introduction so far gives some indications about the issues that this study addresses. The general research problem of the research can be formulated as follows:

Given ill-structured educational and training design situations, in what ways can software tool support students to learn about and to apply a particular method for solving design problems in order to increase the effectiveness of their design activities and performance?

The problem statement is operationalised through a set of more concrete questions in section 1.5 'Research questions'.

The following section introduces the basic theoretical foundations of the study presented as the scientific paradigms mental mapping, problem solving, and learning. More concrete description will be given in Chapter 2, 3, and 4.

1.1.2 Theoretical foundations

The research lies on the cross section of three theoretical perspectives - mapping, problem solving design and learning. From one side, mapping is an ideal construct built upon similarities in the existing mapping methods. Some of these methods are concept mapping (Novak & Gowin, 1984; Novak, 1998); mind mapping (Buzan & Buzan, 1996); cognitive mapping (Eden, Ackerman & Cropper, 1997); process mapping (Hunt, 1998); causal mapping (Eden & Ackerman, 1998; Jenkins, 1998; Laukkanen, 1998; Vennix, 1997); flowscaping (De Bono, 1994), and hexagon mapping (Hodgson, 1999). Each of the mapping approaches has different purposes, different theoretical rationales underlay the methods they propose, and the software they are implemented in is also different. However, all of them use a spatial metaphor to express a way of organising thoughts when a problem-solving situation occurs.

From another side, 'mapping' in this project means a concrete method for implementing the advantages of the referred mapping approaches. It suggests some techniques for getting a global picture of a problem space, for seeing the relationships between components of a problem situation, and for manipulating ideas in order to provoke breakthroughs from dominant thinking pattern.

The idea of mapping is based on some recent research in the field of physiology and psychology (Buzan & Buzan, 1996; De Bono, 1994). Mapping is one of the very few if not single technique that reflects the way the human mind manages information. Mapping mirrors the organisation of thoughts. It reduces the cognitive overload by extending the capacity of short-term memory while externalising internal thinking models. Mapping gives an opportunity to see relationships between different knowledge objects and to manipulate them in order to change the dominant thinking pattern.

The *problem solving perspective* in this study is represented by a taxonomy of a problem solving process, problem solving approaches and methodologies, creative problem solving principles and techniques, and negative conditions for problem solving. The problem solving process includes at least stages such as problem identification, analysis of information, idea generation, idea selection and solution implementation (Van Gundy, 1992). The problem solving perspective calls for a systematic approach that includes a sequence of well-defined stages and possible iteration between them. There are two general problem solving approaches that are subjects of a consideration in this study - reducing complexity and managing complexity of problem situations. The problem solving methodologies analysed in the current research are the rational approach to problem solving, brainstorming, soft system methodology, and synectics. In addition, the method for solving design problems loosely refers to some creative problem solving techniques such as attribute listing, morphological analysis, analogies, metaphors, free association, brainwriting, listing, lateral thinking techniques and tools, weighting systems, and potential problem analysis (Van Gundy, 1992). Principles such as deferred judgement, quantity breeds quality, make the strange familiar, make familiar strange, and include both divergent and convergent activities are taken into account as well.

Mapping and problem solving theoretical paradigms both contribute to development of the SMILE problem solving method which is the part of the SMILE Maker tool. The SMILE Maker tool proposes also a *learning method* for studying and applying SMILE problem solving method. The SMILE Maker as a learning tool integrates some components from cognitive flexibility theory (Spiro & Jehng, J. -C., 1990) and cognitive apprenticeship approach (Collins, Brown and Newman, 1989). The learning environment of SMILE Maker attempts to individualize studying the problem solving method accommodating learning styles, problem solving styles, learning locus of control and level of prior knowledge of users.

In addition to the analysis of existing theoretical paradigms of problem solving, mental mapping and learning, the current study also takes insight form the educational practice of applying concept mapping in solving design problems. The forthcoming section presents results of a preliminary investigation that was conducted in order to get a general impression of what might be possible issues in applying concept mapping in the educational design process.

1.1.3 Preliminary research in the current project

The course '*Linear and Hypermedia*' for third-year students might be considered as a representative case for the way in which concept mapping has been promoted in the educational design practice of the Faculty of Educational Science and Technology. Students enrolled in the course are given an instructional task to develop a computer program using particular software (Authorware) in order to popularise the way Dutch cheese is produced. In the so-called conceptual design phase, students working in groups have to prepare a concept map using 'Inspiration' software (1999, http://www.inspiration.com/home.cfm). The concept map is supposed to help the students in arriving at good design solutions.

Some observations and interviews with students within the framework of a small-scale exploratory study were conducted at the beginning of the current project (September 1997) in order to identify some possible problems in using concept mapping in the design process, and to draw some directions for improvements. The research methodology was not built on an experimental design basis although two groups of students were involved and an intervention was undertaken with the 'experimental' group. The interviews with students from the control group revealed that they had struggled to understand the purpose of concept mapping in the design process. They considered the concept map as a sort of assignment to deliver at a certain stage, but missed seeing the real value of concept mapping as a facilitative design tool. The observation showed that the maps of the 'control' group' were all about the content - Dutch cheese production. They did not contain any instructional design notions as to how the content eventually should be introduced to users. It was expected that students would integrate concept mapping at least in the planning-by-objectives educational design model (need assessment, defining learning objectives, discussing selection of instructional strategy, and evaluation), which was the dominant educational design paradigm. Apparently concept mapping did not transfer the knowledge about design into a design blueprint that could lead designers throughout the whole process. Applying the graphical convention of concept mapping did not directly lead to good design solutions. If concept mapping is considered as a graphical technique for knowledge representation the result was no more than a graphical organizer of the content. Ineffective use of concept mapping in the design process was due to the assumption that the technique affords, just by the fact of its application, a production of good design solutions. In addition concept mapping did not play a role as a shared communication medium for the team members to discuss the main variables of the design and to guide them through the design process. This preliminary study confirmed the expectations of the author based on his experience with concept mapping in the course 'Instrumentation for Education and Training' within the framework of MSc program 'Educational and Training System Design' also in the Faculty. There were not considerable distinctions in the way concept mapping was introduced and used in the courses 'Instrumentation for Education and Training' and 'Linear and Hypermedia'.

To become a design tool, concept mapping should apply a specific knowledge that goes beyond the graphical convention of concept mapping. The technique should take into account the context of designing of an educational product, which could modify considerably formal design models represented by concept mapping. The context gives the direction of applying the graphical convention of the technique. Concept mapping should support the analysis of the design situation, generation of design ideas, selection of the most appropriate one, and implementation into a prototype product. The technique should be introduced not only as knowledge representation technique but also as knowledge elicitation, knowledge reflection and knowledge creation technique. Concept mapping as knowledge elicitation technique would support articulation of knowledge about design. Concept mapping as knowledge reflection technique could analyse, restructure, and modify elicited design knowledge. Concept mapping as knowledge creation technique could create original and feasible design solutions.

Students in the 'experimental group' experienced a simple intervention. They were facilitated during a short brainstorming session where some concept mapping templates, rules and a structure of the discussion were given. Students got a template in the format of a concept map consisting of a number of variables. Participants brainstormed on each of the variables such as content, instructional design issues (objectives, target group, instructional strategies), program design issues (media selection, navigation, screen design) to get a picture of the relationships between these main design variables.

As a result the experimental group produced richer maps in terms of number, scope, feasibility, visibility and originality of the design ideas, compared to the 'control' group. However the study limited itself to the conceptual design phase and it did not provide clear indications as to what the impact of the intervention to the final design product would be. While this research put its emphasis on the idea generation it did not pay enough attention to idea selection and idea implementation support. This preliminary study indicated the need for a distinction to be made between the different functions concept mapping may perform. Concept mapping as a *graphical tool* can represent any sort of content. As a *teaching tool* concept mapping can be used as an advanced organizer of the logical structure of a particular subject matter. As *a learning tool*, concept mapping supports students to integrate new knowledge in existing knowledge schemes and cognitive structures. Concept mapping as a *design tool* facilitates orientation in the design situation, generation of ideas, selection of the most appropriate solution(s) and implementation of selected design solutions into practice. This preliminary research introduced the idea of combining mapping (concept mapping) and problem solving (brainstorming). The next section discusses the contribution of the theoretical perspective of problem solving design for improving the process of solving educational and training design problems.

1.2 Solving design problems

This section (Section 1.2.1) begins with a discussion of why and in what respects problem solving and design are used interchangeably and as complementary to each other. Following that in Section 1.2.2, an overview of some existing educational design approaches is presented. Some tendencies and issues similar in the domains of education, engineering and business management are identified in Sections 1.2.3 and 1.2.4. Section 1.2.5 presents some negative problem solving syndromes that may interfere with the effectiveness of problem solving. The concluding Section 1.2.6 formulates the main issues of educational and training design that are to be addressed.

1.2.1 Design and problem solving

The terms 'problem solving' and 'design' have been used interchangeably in the literature about educational design, engineering design and management consulting (Block, 2000; Dabbagh, Jonassen, Yueh & Samouilova, 2000; Hutchinson & Karsnitz, 1994; Shein, 1999; Schön, 1996; Tekinerdogan, 2000). The following examples taken from different domains are indicative of the close link between design and problem solving.

- Simon (1972) in a study that has become a classic for problem solving believed that all professional practice is concerned with what he calls 'design', that is with the process of 'changing existing situations into preferred ones'. He identified a tendency among professionals to think of policies, institutions, and behaviour itself as objects of design. This suggests the existence of a generic design process that underlies the differences among professional domains.

- Schön (1996) in a book influential to professional practice raised a voice for a paradigmatic shift from Technical Rationality to Reflection-in-Action epistemology. Technical Rationality consisting of context-free formal approaches that failed to adequately match knowledge patterns to ill-structured problem situations. Schön identified this problem as common for all professional domains, among them medicine, engineering, architecture, psychotherapy, education, town planning and social welfare. He proposed reflection-in-action as a relevant approach for dealing with the complexity, uncertainty, instability, uniqueness, and value conflicts of real-life situations. Schön defined design as a reflective conversation with the problem situation where problem solver constructed the problem. Problems are not givens as the Technical Rationality Approach suggests.

- Dabbagh, Jonassen, Yueh and Samouilova (2000) described instructional design as an ill-structured problem solving process that is defined by the context of the problem, the knowledge and skills of the instructional designer, and the quality of available resources. The critical point according to the authors is that instructional design is a dynamic process of problem understanding and problem solution. Instructional designers have to address unique and complex problems rather than treating instructional design as a well-structured problem-solving process.
- According to Hutchinson and Karsnitz (1994) design describes the process of developing solutions to a problem. Problem analysis and problem definition are parts of the general design model in engineering (Cross, 2000). Tekinerdogan (2000) defends the position that software engineering and any kind of engineering can be considered as a problem solving process. To understand engineering design, it is necessary to understand problem solving.
- One of the core modules of the MSc programme Educational and Training System Design at the Faculty of Educational Science and Technology at University of Twente is 'Methodology for Educational and Training Problem Solving'. The content of the module is about various design models and approaches.
- Students in the Faculty of Educational Science and Technology are involved in problem-based learning. They are confronted with real-life educational or training situations where the task is designing a product, or a solution. Although there are many instructional design models or learning environments that use problems (case-based learning, action learning, goal-based scenario, and project based learning) problem-based learning is the most extensive and complex in putting the problem to use (Dabbagh, Jonassen, Yueh, & Samouilova, 2000).
- Creativity is another common issue traditionally related to both problem solving and design. Most of the problem solving methodologies and design approaches include methods and techniques for breaking down the dominant thinking pattern and coming up with some non-traditional solutions. Creativity is one of the most powerful drivers for gaining an advantage in an unpredictable environment. It is not considered as an inborn gift. Creativity can be learned and developed (Clegg & Birch, 1999; Jay, 2000; Michalko, 1998).
- In The Netherlands one of the biggest players on the field of creative problem solving is the Faculty of Industrial Design at University of Delft. The curricula of the Faculty of Management and Technology at University of Twente include the courses *Creative*

Problem Solving and *Innovation.* The DINKEL Institute at the same university offers a course and workshops on creativity with an intention to facilitate the professional activities of instructors in the field of curriculum development and instructional design.

The term ‘problem solving design’ might be interpreted at least in three ways: ‘solving design problems’, ‘problem solving in the design process, and ‘designing problem solutions’. Basically they reflect one and the same reality but emphasize different aspects.

‘Solving design problems’ focuses on the specifics of *design problems*. Most of the non-routine and innovative design tasks are ill-structured. There are at least three characteristics of ill-structured design situations: complex, vague, and incomplete information; no agreement about the right solution; and lack of a clear-cut procedure as to how to proceed. Complexity and uncertainty characterize most of the educational and training design situations. Many factors play a role, the interactions are unclear and almost constantly changing, and there are not comprehensive theories for the underlying processes that are accepted by the scientific community (Moonen, 1999). Some examples of educational design problems might be: designing an instructional Web site, changing traditional corporate training paradigms to e-learning solutions, establishing a corporate university, or redesigning a national curricula in a particular country, to mention a few.

‘Problem solving in design’ emphasizes the *process characteristics of problem solving* in terms of stages, consequences, and iteration. Problem solving has a long scientific history and some of the theoretical and practical evidence in this paradigm might be useful for improving the design process.

The concept of ‘designing problem solutions’ connotes *tools, procedures, and techniques* to be applied to an object in order to produce some deliverables. It brings to problem solving the practical notions of instruments and instrumental knowledge in addition to cognitive phenomena of perception, memory and thinking.

Whatever concept is selected it should reflect the processes, techniques, rules and tools for analysing the design situation, generating design solutions, selecting the most feasible of them and implementing it into a design product. For convenience the notion ‘solving design problems’ will be used throughout the study.

The concept of ‘solving design problems’ includes some essential characteristics that are common for any sort of design - educational, engineering, or consulting. The specifics come from the domain they are applied to. The following three sections (1.2.2; 1.2.3; 1.2.4) present tendencies and issues similar for educational and training design, engineering design and consulting methodology.

1.2.2 Educational design methodologies

Solving design problems is interpreted in a number of educational and training design methodologies. Some commonly referred to methodologies are planning-by-objectives, deliberative, prototyping and artistic paradigms (Visscher-Voerman, Gustafson & Plomp, 1999). Some of the activities traditionally attributed to one of the paradigms can be recognized in some degree in each of the others but the functions are different. Variability across the tasks and personal characteristics of designers can be identified as well. Depending on task, resources, and the complexity of the situation designers sharing the same approach may vary in details, or different design rationales might underpin their activities for specific projects. While the four above-mentioned design paradigms are not considered as completely exclusive, the emphasis in the Visscher-Voerman, Gustafson and Plomp analysis was put on the differences and uniqueness of each of the processes. A distinction was made on the basis of a 'neither-or' rule: for example, instrumental or deliberative, or prototyping, or artistic approach.

A step further in developing design methodologies is the tendency for combining some of the activities and techniques of different design approaches (Collis & de Boer, 1999; Kessels, 1999; Kommers, 2000; Moonen, 1999, 2000, in press). Some examples of this tendency are as follows:

- Moonen (1999, 2000, in press) distinguishes between rational and relational design strategies. He identifies the needs for establishing a balance between them and proposes a solution: the 3-Space Design Strategy (1999, 2000a, 2000b). In this model three types of spaces are conceptualised - consensus, task and implementation. Within each of these three layers both rational and relational types of activities are recognized. Rational approaches have a close similarity to the planning-by-objective paradigm and relational activities have close conceptual relations with the deliberative paradigm. On a more general level the consensus space is influenced by the deliberative approach and the task space is affected by research and practice related to prototyping. Implementation involves consensus and task activities with regard to end users.

- Collis and de Boer (1999) applied the 3-Space Design Strategy in practice when developing a decision support tool for the needs of the course management system TeleTOP. They also added an integration of instructional design models based on a classification consisting of classroom, product and system orientation dimensions.

- Kommers (2000) recommends four stages in hypermedia design: conceptual, metaphoric, structural, and navigational. Conceptual design represents schematically the ideal product. Concept mapping, mind mapping and brainstorming can be useful at this stage. Conceptual schemas play the role of a shared communication medium for the members of the design team. Metaphorical design is about finding a convincing and attractive image or word to express in a concise but rich fashion the main idea of the program. Structural design proposes the structure of the hypermedia program. Navigational design suggests how users can orient themselves and go through the program.

- Kessels (1999) advocates the combination of a systematic approach and a relational approach as premise for the design of a successful corporate curriculum. The systematic approach contributes to the internal consistency of the curriculum including such components as need analysis, target group needs analysis, formulating of learning objectives, and selecting of instructional strategies. He defines the external consistency of the corporate curriculum as the coherence between perceptions of the main stakeholders about what the problem is about and how it can be solved. Kessels claims further that relational aspects predict most accurately a positive program effect.
- Collis, Peters and Pals (2001) developed and validated the 4E Model for predicting the end user's acceptance of technological innovations in her or his educational related activities. The model consists of four concepts: environment, effectiveness, easy of use, and engagement. The practical implication for the educational and training design is the idea of keeping in mind the 4E Model from the very early stages of design process in order to increase the likelihood of using the product.
- Dabbagh, Jonassen, Yueh and Samouilova (2000) define the instructional design process as a conjunction of creative and rational processes. They argue that teaching instructional design should focus more on the problem attributes and not the model with context free rules.

The tendency towards recognizing the importance of involving both a systematic rational strategy and a relational context-based approach for solving design problems can be illustrated in some other professional fields. It is not the purpose of this analysis to refer to all of them. Here the cases of engineering design and business management methodologies will be discussed in more details.

1.2.3 Software design methodologies

Several process models have been used in software design: the waterfall model, V-process model, spiral model, prototyping, and incremental delivery (Cotterell & Hughes, 1996). The V-process and spiral models are an elaboration of the classical waterfall model, and incremental delivery is a modification of incremental prototyping. Waterfall, V-process and spiral models are conceptually similar to the planning-by-objects educational and training design methodology. Prototyping models in software design have inspired some initial insights in the education and training design domain. Software design paradigms have shifted their emphases from instrumentally oriented design methodologies towards more 'social oriented methodologies' (Conger, 1994; DeGrace & Stahl, 1990; Stahl, 1993). The same tendency of paying attention not only to an instrumental or rational approach but also to deliberative or relational approach in educational and training design methodology was discussed in the previous section. The main drives for this change in software design methodology were series of implementation failures of some otherwise very well designed and technically developed software design solutions. 'Social methodologies' include user-involvement techniques such as joint application design, socio-technical systems, and ethics. Software designers are beginning to assume end-user involvement as mandatory to effective implementation of software production (Conger, 1994). Some examples of emphases shift in the software design methodology are as follows:

- The All-at-Once model for software development claims that all phases of the design process should be done concurrently. It exists in team, two-man, and one-man formats (DeGrace & Stahl, 1990). The team format adopted Japanese 'Sashimi' and 'Scrum' approaches. It emphases negotiations and discussions, suggesting similarities with the deliberate approach in educational and training design. The *handcuffing* or two-man approach involves the end user in the analysis, design, development and implementation activities. A direct link to the 3-Space Model of Moonen (1999, 2000, 2000 in press) can easily be recognized. The one-man approach or *hacking* draws attention to high individual performances. Some good examples for this approach include high profile personalities such as Bill Gates (Microsoft), John Page (Hewlett-Packard) and John Warnock (Adobe). This approach known with the name 'learn-as-you-go' in some other sources (Conger, 1994) is popular as the artistic approach in education and training design domain (Visscher-Voerman, Gustafson & Plomp, 1999).
- Stahl (1993) in his doctoral dissertation developed and applied a theory for computer support of *interpretation in innovative design*. The theory is based on the philosophy of Heidegger applied to some design approaches in different field. Stahl also developed a computer program *HERMES* to support NASA lunar habitat design.
- In order to understand the substantial inherent problems of software design and to suggest some solutions to what he called the 'software crisis', Tekinerdogan (2000) analysed and applied some basic philosophical and psychological theories about problem solving to

software design. He also referred to problem solving approaches in so-called 'matured' engineering (electrical, mechanical, civil, and chemical).

- So-called 'matured' engineering disciplines also combine formal rational and creative design methods (Cross, 2000). Cross generalized the engineering design structure emphasizing problem analysis and definition, conceptual design and embodiment design. He found two common characteristics of the design methods - formalizing and externalising. Formalization tries to avoid the occurrence of oversights and overlooked factors in the design problems, and the errors that might happen through these oversights. Externalising is about getting thinking processes out of the minds of designers and representing them in diagrams and Schemes. This is especially important when dealing with ill-structured problems. Cross believes that some creative problem solving techniques such as brainstorming and synectics might be a help to any type of design.

In a certain sense, 'matured' engineering professions are prototype examples showing the 'zone of proximate development' for other younger engineering disciplines. It should be expected in a certain amount of time that software engineering methodology would adopt not only the formal but also creative design methods and techniques. The interesting point in this line of reasoning is the position of educational design methodologies. They follow the advancements of the design methodologies of the engineering disciplines. But they are also expected to develop and provide some design approaches, methods and techniques to enrich the design methodologies of other design disciplines. A modest contribution to that effort might involve concept mapping and other mental mapping approaches being applied in design processes.

The same tendency towards using more informal and interpretative thinking Schemes have been applied in the domain of business management and organizational learning.

1.2.4 Design of business management solutions

The 'design of business solutions' reflects all cases of problem solving in ill-structured business situations. Heiden and Eden (1998) discuss the rationalistic, evolutionary and processual views of strategy that may be used to illustrate different approaches to organizational learning. The rationalistic approach has almost the same characteristics as the instrumental approach in education and training design. The evolutionary strategy suggests similarities to the prototyping approach. The processual approach can be seen as parallel with the deliberative approach for education and training design. According to Heiden and Eden it is more productive to see these approaches as three aspects of a single complex phenomenon rather than preferring one to another.

In the literature about management consulting the focus has shifted from consulting models that prescribe to the client what to do or acting on behalf of him towards relationships that support collaboration in problem solving. Schein (1999) valued mostly the process model consulting on the expense of purchase and doctor-patient model. According to the purchase model the consultant is viewed as a seller and is expected to deliver some ‘goods’ in the form of information, service, and product. In the doctor-patient model, the client initiates relationships by stating the concerns about the existing situation. The consultant has the authority and skills to carry out a diagnosis and the client should accept the solution. This model used to be the dominant model in the domain of management consulting. According to the process model the consultant and client go through the process of problem solving together. It is supposed that the client is deeply involved in the problem while the consultant assists in better understanding what the real problem is and proposes methods how it could be solved.

In a similar way Block (2000) distinguishes between expert role, pair-of-hands role and collaborative role of the consultant. The consultant who accepts a collaborative role joins his or her specialized knowledge with client’s knowledge of organization. Problem solving is a joint undertaking, with equal attention on both technical issues and human interactions. The consultants in this role do not solve the problems for the client. They apply their special skills to help client to solve problem. During problem solving process, the client acquires the method of problem solving from the consultant. The key assumption in the collaborative model is that the client must be actively involved in collecting and analysing data, setting goals and developing action plan, and certainly in sharing responsibilities for success or failure.

The analysis of educational and training design, software design and management consulting approaches showed that they share some common tendencies. In addition, the research on software design approaches and management consulting methodologies prompted the idea of deeper exploration of the issues that might occur during problem solving in design situations.

The rational approach to problem solving is still in operation, but gradually more consideration is being given to more ‘soft’ methodologies and techniques such as *Brainstorming*, *Soft System*, and *Synectics*. These apply more sensitivity to establishing a positive climate for discussing, supporting expressiveness of ideas, and facilitating non-traditional ways of looking at the issue. These problem-solving approaches try to avoid some of the negative problem solving syndromes that always tend to occur in ill-structured problem situations. The next section, 1.2.5, discusses some conditions that may affect individual and group problem solving effectiveness.

1.2.5 Negative problem solving syndromes

One of the most frequently observed facts is that people, who may otherwise be very good subject matter experts, often struggle to shape their problem solving activities in the most effective and efficient way (De Bono, 1990; Van Gundy, 1992; Wagner 1992). There are at least five types of difficulties they might experience:

- *Elicitation of tacit knowledge*. Sometimes people are not aware how much they know or they could not express their full potential as experts.
- *Organisation of explicit expert knowledge*. This is a matter of an effective and an efficient management of the explicit knowledge - how to use available knowledge in the best way. Facilitation is needed in the collection and analysis of information, idea generation, selection of the best solution candidate, and solution implementation.
- *Negative individual problem solving deficiencies*. A manifestation of some problem solving deficiencies in an ill-structured situation has been reported such as ‘analysis-paralysis’, 'functional fixedness', 'lack of insight', and premature judgement' (Wodtke, 1993). It is well known fact that many people develop, for of different reasons, a one-sided approach of looking at problems. Some of them are good in the collection and analysis of information (seekers), some others are strong in the generation of ideas (divergers), a third group is the best in the selection of ideas (convergers), and a fourth group includes people who are confident in implementation of the ideas (practitioners). People need to develop more complexity, flexibility and versatility of their problem solving styles.
- *Domination of critical thinking*. When discussing complex and vague information, people tend to be quick in arguing against other opinions. There are many personal creativity ‘killers’. Therefore some rules have to be established in order to build creativity and an innovation supportive environment. Individuals also tend, because of different reasons, to discard some valuable ideas at the very early stage of problem solving. This does not mean that critical thinking should be ignored completely. On the contrary it is very important, but should be controlled at the very early stages of problem solving in order to give chance of the non-ordinary ideas.

These potential problem-solving deficiencies have a negative impact on the performance of people in ill-structured design situations. A method that is supposed to support solving design problems should pose means to deal with these negative problem solving syndromes. In the following section, 1.2.6, some other problems in educational and training design are reported.

1.2.6 Educational and training design issues

The overview of design approaches in the domain of education and training, software, and management design reveals the tendency across disciplines for combining rational and relational approaches, formal and informal strategies, and 'hard' and 'soft' methods in design activities. The analysis also identified some gaps that should be covered. Some of the most essential issues in educational and training design are listed bellow. A few brief suggestions for overcoming those obstacles are presented as well.

- Operational support in the terms of procedures and techniques for structuring individual and group activities is needed. To recognise the need of involvement the stakeholders in all phases of the design process is a positive step, but not enough. People need guidance and concrete techniques and tools to discuses issues. The existing educational design approaches provide a valuable framework for design activities, but do not go further on a more detailed level to support an analysis of the design situation, collection of needed information, generation of alternative solutions, selection and implementation of solution. They do not propose instrumental knowledge, techniques, tools, guidelines, and procedures for these design activities.
- Ideally a method for solving design problems should be a substantial part of an integrated design methodology including components from the rational, deliberative, prototyping and artistic approaches. This methodology might be built upon advanced knowledge about mental mapping and problem solving, and is based on modern technology in order to support non-routine and innovative education and training design activities. It should based on strong scientific knowledge, be operational, have practical instrumental value, and include 'hard' and 'soft' procedures and techniques. The methodology should support people in the collection of information about a design situation, generation of design ideas, selection of ideas and implementation of design solutions. Educational and training designers not only recognize the need for overcoming the limitations of context-independent approaches in the framework of technical rationality epistemology (Schön, 1996). They promote new conceptual Schemes based on context-dependent approaches keeping in operation the strong characteristics of the formal systematic approaches.
- Any design methodology should take into account the effects of negative problem solving syndromes on solving design problems. Facilitation of individual and group knowledge management is a way of getting the full potential and the expertise of people involved in the design of educational products or services. Any design methodology should supports the articulation of tacit knowledge and the effective management of explicit knowledge in

terms of the analysis of information, collection of information, idea generation, idea selection, and idea implementation. It should help in developing a flexible and versatile individual problem solving style and in establishing a striking balance between critical and creative thinking.

In order to deal with the issues of the educational and training design the current study aims at designing, developing and evaluating a method that support the process solving educational and training design problems. In the next section, 1.3, a closer look is taken at how mental mapping can contributes to development of a method that facilitates the solving of ill-structured design problems.

1.3 Mapping

This section aims at giving a first impression of concept mapping and other mapping approaches and to highlight the main issues of using mapping for design purposes. The section includes the following parts: 1.3.1 Concept Mapping in Education, 1.3.2 Other Mapping Approaches, and 1.3.3 Concept Mapping in Faculty of Educational Science and Technology. Section 1.3.1 Concept Mapping in Education presents the dominant view on concept mapping as the most popular mapping technique in education. Section 1.3.2 includes short descriptions of different mapping approaches. Each of them is presented in terms of method, theoretical framework and software. The theory and practice of using concept mapping at the Faculty of Educational Science and Technology at University of Twente are discussed in Section 1.3.3. Section 1.3.4 summarises the main issues of applying concept mapping in the educational and training design process.

1.3.1 Concept mapping in education

Concept mapping can be defined as a graphical technique representing concepts and their interrelationships in a given knowledge domain. It has been long considered as a valuable educational method (Ahlberg, 1993; Beyerbach, 1988; Grant, 1998; Hale, 1998; Hammond, 1998; Lambiote, Dansereau, Cross & Reynolds, 1989; McAleese 1998; Sherry & Trigg, 1996; Zaff, McNeese & Snyder, 1993). The technique has been used mostly as a graphical advance organizer, an assessment tool in teaching, and as a technique promoting meaningful learning. (Laffey & Singer, 1998; Novak & Gowin, 1984; Novak, 1998; Pedley, Bretz, & Novak, 1994). Concept mapping is based on assimilation theory (Ausubel, Novak, & Hanesian 1978) and promotes meaningful learning among students. Applying a simple graphical convention consisting of hierarchical spatial configuration sets of nodes and labelled links between nodes, concept mapping represents the logical structure of a subject matter. Concept mapping facilitates students to understand and build up a psychological model of this structure. More recently the method has been applied in business settings (Novak, 1998) to support individual and organizational learning. The classical view on concept mapping (Jonassen, Reeves, Hong, Harvey & Peters, 1998; Kennedy & McNaught, 1998; Kommers &, Lanzing, 1998; Novak & Gowin 1984; Novak, 1998) presents the technique predominately as a knowledge representation device that supports understanding of learning material.

The following section discusses the way concept mapping is being interpreted and applied in a concrete educational setting - the Faculty of Educational Science and Technology at University of Twente.

1.3.2 Concept mapping in the Faculty of Educational Science and Technology

The view of concept mapping as a knowledge representation technique was adopted as a theoretical orientation and has been applied to different contexts involving educational and training design practice in the Faculty of Educational Science and Technology. Heeren and Kommers (1992) in an experiment investigated the flexibility of expressiveness of three cognitive computer tools that used concept mapping as knowledge representation. They concluded that a concept-mapping tool should be flexible with respect to the expressiveness of the method of knowledge representation that it offers. Heeren and Kommers assumed that improving the capacity of concept mapping, as a drawing tool would have a direct effect to learning effectiveness. The results of this study were used for designing a new concept-mapping tool.

Kommers (Kommers, Ferreira, & Kwak 1998) investigated the possibilities of the concept mapping software (TextVision 2D and 3D versions) that he developed to explore the conceptual space in terms of computation and the representation of concept centrality. Kommers and Lanzing (1998) defined five functions that concept mapping can support: orient students, articulate prior and final knowledge, exchange views and ideas among students at a distance, transfer learned knowledge between different topics and domains, and diagnose misconceptions. More recently Kommers explored the role of different mapping methods and tools in the hypermedia design process (Kommers, 2000).

Concept mapping is maybe the most popular mapping technique in education, but it is not a single one. There are some other mapping techniques, which are presented in the next section. They might also have an impact on developing mapping as a contribution to a method for solving design problems.

1.3.3 Other mapping approaches

Concept mapping and mind mapping (to a considerably less extent) have dominated the choice of mapping approaches in educational practice (Beyerbach, 1988; Grant, 1998; Hale, 1998; Hammond, 1998; Lambiote & Dansereau, Cross & Reynolds, 1989; McAleese 1998). This has put out of sight some other mapping approaches such as cognitive mapping, causal mapping, process mapping, information mapping, flowscaping, and hexagon mapping. They have become more popular in the domain of business and management science. All of these additional mapping approaches could have a valuable contribution to improving the quality of mapping in the educational and training design process and bring some new perspectives to the issue. A short description of those mapping approaches follows:

- Mind mapping has been introduced as an explicit model of the associative way the human mind organises information. Mind mapping uses natural free association and can be used as a brainstorming technique in problem solving (Buzan & Buzan, 1996). Software tools available for mind mapping are *Mind Manager* software (1998, http://www.mindman.com/), and *VisiMap* (http://www.coco.co.uk/)
- Cognitive mapping has been described as a tool for reflective thinking and problem solving (Eden, Ackerman & Cropper, 1997). It aims at helping people to make a sense of complex ill-structured situations and to decide what to do and how to proceed with them. The theoretical rational behind cognitive mapping is Kelly's Personal Construct Theory (1955, cited in Eden et al). The approach is implemented in the *Decision Explorer* software (2000, http://www.banxia.com/demain.html).
- Causal mapping (Eden & Ackerman, 1998; Jenkins, 1998; Laukkanen, 1998; Vennix, 1997) is a graphical device to represent and analyse the structure and causal relationships between components of complex situations. Causal mapping represents cognition as a set of causal interactions. Various theories are used as a basis for causal mapping. The most referred are schemata theory, attribution theory and theory of mental models. Software tools that are recommended for causal mapping are STELLA (http://www.hps-inc.com/edu/stella/stella.htm) and iThink (http://www.hps-inc.com/bus_solu/ithink/ithink.htm).

Cognitive and causal mapping are the most substantial part of the Soft System problem solving methodology (Hicks, 1993; Hofman, 1995) that is gradually taking over from the 'hard' methodology (Vennix, 1997). 'Hard' methodology relies mostly on formal methods for analysing business problems. It failed in attempts to deal adequately with ill-structured situations (Vennix, 1997). 'Soft' system thinking should be seen as the general case and 'hard' system thinking is the occasional special case. As a general rule, the 'hard' system approaches such as Operational Research, System Engineering and Structural System Analysis are appropriate when the problems are well defined and the goals, objectives and means are clear. If the case is open and ill structured, and there is not agreement on the ends and means, then 'soft' system methodology is more appropriate.

- Hexagon mapping (Hodgson, 1999) is a visual brainstorming method originally using magnetic hexagons. More recently a software tool '*Idons-for-Thinking*' (http://www.idonresources.com/) for supporting this type of mapping has been popularised. Hexagon mapping is described as dynamic representation modelling. The approach supports thinking through visual entities called idons, a composed notion that is a combination of idea and icon. Idons can be manipulated, combined and rearranged to facilitate the generation of ideas. To enhance the support thinking, colours are added to idons. Sometimes hexagon mapping is used together with causal mapping (Vennix, 1997). Hexagon mapping is based on the principles of dynamic modelling (Heiden, & Eden, 1998; Vennix, 1997) and creative thinking (Clegg & Birch, 1999; Jay, 2000; Michalko, 1998).

- Flowscaping (De Bono, 1994) tries to grasp graphically the perception of a problem space at a particular moment. In order to know what to do when a problem occurs we have to understand our perception of the situation. Thinking, according to De Bono, is a two-stage process - making and using maps.

- Process mapping is a management tool describing in workflow diagrams and supporting text the whole cycle and components of any process (Hunt, 1998). The software tools that are linked to process mapping are Visio (http://www.microsoft.com/office/visio/evaluation.htm), FlowMap (http://www.flowmap.com/), ProVision (http://www.proformacorp.com/) and SynXpert (http://www.mirusgroup.com/index.html).

In the business setting, mental mapping, especially hexagon mapping and causal mapping in the format of model building, has been used not only as knowledge representation, but also as knowledge elicitation and knowledge creation techniques. System dynamic model combines causal mapping with creative problem solving methods such as the Delphi method and Nominal group technique (Vennix, 1997). Hexagon mapping includes steps such as brainstorming, clustering, influence diagram and convergent thinking.

Section 1.3.4 Concept mapping issues summarizes some of the problems that occur when concept mapping is used in the educational and training design process.

1.3.4 Concept mapping issues

The issues listed in this section reflect reasons why concept mapping did not reach the level of expectations that students and teachers attributed to the technique for supporting educational and training design. Shortly the reasons can be described as follows: concept mapping is considered mostly as a instruction or learning advanced organiser, not as a design blueprint; concept mapping is treated mostly as knowledge representation technique, not as a knowledge elicitation, knowledge reflection and knowledge creation technique; concept mapping software serves mostly as a graphical editor but does not support knowledge about concept mapping method; concept mapping is thought of as the only mapping approach, while other mapping approaches are neglected. The remainder of this section presents these concept mapping issues in more detail.

- Concept mapping as a *design technique* serves different functions than concept mapping as a *teaching and learning technique*. This statement should not be misinterpreted that learning does not take place in design process. What it emphases is that concept mapping as a teaching and learning technique supports different kind of activities and psychological functions than concept mapping as a design technique. Concept mapping as learning and teaching technique is concerned with the organization of the predefined content of a particular subject matter. Students should assimilate this content in their existing knowledge structures. Concept mapping as a learning technique supports the relatively low levels of the learning taxonomy - remembering and comprehending. In a design process concept mapping facilitates higher levels of the learning taxonomy - applying and mostly problem solving, in what can be described as learning-by-designing. Students are faced with a real, authentic design situation that is normally ill structured, and they have to solve this problem and come up with some feasible and original solutions. During this process they learn by doing getting learning experience and reflecting on it. In these sorts of cases, concept mapping should offer a different type of support. It might lead students through a process of solving design problem providing support for collecting information and analysing the current situation, generating alternative solutions, selecting the most appropriate one(s) and implementing the solution into practice.

- Concept mapping has been treated mostly as *knowledge representation technique*. There are two issues here. Firstly, in a typical case concept mapping should guide students to describe the situation both in the terms of content and the format of presentation. However, in the case of the course *Linear & Hypermedia* concept mapping was considered mainly as a content supportive technique. Students in the control group made maps containing only items about the content - Dutch cheese production. They did not take into consideration factors such as target group, learning objectives, instructional approaches and evaluation, program structure, navigation, screen design, and media selection. Secondly, the function of concept mapping as knowledge representation technique is important but not enough for the design process. Concept mapping should be considered also as a technique supporting knowledge elicitation, knowledge reflection, and knowledge creation. There are at least three points in respect to concept mapping as a knowledge elicitation technique. Firstly, the external information about design problems is very complex, messy, vague and incomplete. Secondly, there are some difficulties related to the articulation of structural knowledge that is stored in the long-term memory of individual. He or she should recognize and select the most appropriate piece of knowledge according to the design situation. Thirdly, short term memory being a meeting place for external stimulus about a design problem and the knowledge of an individual has a limited capacity to deal with the increasing number and sometimes contradictory nature of information items. It is very difficult to think of and find relationships among all the information items that are related to a design issue. Concept mapping can extend the capacity of short-term memory as externalising what happens in it. Concept mapping makes the process of bringing together personal knowledge and external information about the design problem easier. The internal thinking model about a design situation can be *represented* through the concept mapping graphical convention. All knowledge items are connected in a personal meaningful way and links are labelled. Concept mapping as a *knowledge reflection* technique should help in analysing the model of a design situation. New groups of items and a new structure of the model can be formed. Externalisation of internal problem solving representation activates perception as an additional psychological function to enhance thinking. It is easier to recognize something that is available and visible than to retrieve it from long-term memory. Concept mapping increases the effectiveness of the reflection-in and reflection-on design processes in an open ended situation because it reduces considerably cognitive overload through externalisation of internal problem solving representations and extends the capacity of working memory. Elicitation, representation and reflection stimulate *creation* of new knowledge. Concept mapping could provoke changing the configuration of knowledge patterns and creation of new ideas. The unique characteristics of concept mapping are in their best together with some problem solving techniques.

- When *concept-mapping software* is discussed the focus is put mostly on its characteristics as a *drawing* tool - making nodes, drawing links, posting labels, and changing shapes and colours. All efforts have been directed to designing a concept mapping tool as a graphical editor. The issues about how the tool might support the process of eliciting, reflecting and creating design ideas had been left out of consideration. There is also a tendency for overestimating the design power of concept mapping graphical convention. Drawing a diagram consisting of nodes, links and labels on the links do not directly lead to designing good solutions. Eliciting, reflecting, representing and creating design solutions is not embedded in concept mapping as drawing tool. More concrete operational support that goes beyond the graphical functions is needed. No one of the existing mapping software tools provides support about the mapping methods that are implemented in the tools. The help systems of these tools are limited only to instructions on how to use the graphical features of mapping software. There is much of explanation about how to make nodes, links, and labels; how to use libraries; how to change the shape and colours; and how to export to html files. But no information is given about the mapping technique itself: purposes, theoretical framework and procedures. If a user does not know about a particular mapping method it is hard to apply it relying only on the help system of a software tool. This raises the issue concerning learning environments of mapping tools. A learning environment should help users in studying and applying a mapping method reflecting the recent achievements of learning paradigm and advancements of technology.

- Concept mapping has been considered as the only mapping technique. Other mapping approaches exist and they could have a valuable contribution to developing a method for solving design problems. Cognitive mapping could be used to organize complex and messy information in terms of goals, strategic options and operations. Causal mapping could identify the cause-effect chains. Mind mapping has a capacity for information collection and brainstorming. Hexagon mapping could support free association, clustering and causal links; and flowscaping could support identifying the problem and idea generation on principles of lateral thinking.

The issues described under the headings of solving design problems and mental mapping expressed some discrepancies between 'what is' and 'what should be' the situation in relation to the role of mapping in the educational and training design process. The issues lead to research questions that outline the problem space of this study.

1.4 Research questions

This section formulates a number of research questions, which could be considered as an operationalisation of the main research question stated in Section 1.1 'Research context' of this chapter. They reflect the issues of mental mapping and problem solving discussed in the previous section. The research questions are as follows:

- *In what ways could the problem solving paradigm contribute to the development of the SMILE problem solving method? (Chapter 2)*

The problem-solving paradigm might contribute to the development of a problem solving method with problem solving process taxonomy, individual problem solving syndromes, creative problem solving principles and creative problem solving techniques. Attention should be paid to problem solving methodologies such as brainstorming, soft system methodology, rational approach to problem solving, and synectics.

- *Which instructional design theories and approaches constitute the theoretical background of the SMILE Maker Tool? (Chapter 3)*

The study will analyse a number of instructional design paradigms, theories and approaches in order to build a solid theoretical ground for designing the learning environment of the SMILE Maker Tool. Some of them are constructivism, cognitive flexibility theory, cognitive apprenticeship approach, and theories about cognitive and learning styles.

- *In what ways can the paradigm of mental mapping contribute to the development of the SMILE Maker problem solving method? (Chapter 4)*

Different mapping approaches will be studied in order to provoke an insight as to how they could contribute to development of the SMILE problem solving method. Mental mapping approaches will be analysed in the terms of definitions, theoretical framework, procedures and software.

- *What are the design solutions implemented in the SMILE Maker Tool? (Chapter 5)*

The study will demonstrate how the theoretical rationales of mental mapping, problem solving and instructional approaches are transformed into design solutions. It will discuss the design process, design model and the functionality of the SMILE Maker Tool.

- *What is the research methodology of the SMILE Maker Tool evaluation? (Chapter 6)*

The current project will describe the research methodology on which the evaluation of the SMILE Maker Tool is grounded. The project has the ambition to apply different research paradigms, evaluation subjects, data collection methods, measuring instruments, and data analysis techniques to achieve a high level of reliability and validity of the research and to obtain valuable data.

- *What are the characteristics of the SMILE problem solving method that could predict high performance in solving design problems? (Chapter 7)*

The study will describe the methodology, will present some qualitative and quantitative data, and will interpret the results of the research aimed at showing the effectiveness of the SMILE problem solving method. Map production and performance on a case will be analysed.

- *What is the quantitative and qualitative evidence that the SMILE Maker is an effective tool for problem solving? (Chapter 8)*

The study will test the effectiveness of SMILE Maker as learning and problem solving tool searching for both quantitative and qualitative evidence.

- *What are conclusions derived from designing and evaluating the SMILE Maker Tool and what suggestions can be made for improving the tool? (Chapter 9)*

Based on the answers of the previous questions some generalisations about the SMILE problem solving method and the associated learning environment will be formulated and some recommendations for improving the method and learning environment of SMILE Maker Tool will be given. In addition some future research perspectives will be suggested.

1.5 Overview of the study

The study continues with the second chapter ‘Problem solving theories and methodologies’. It presents the problem solving paradigm in the terms of approaches, methodologies, process taxonomy, and individual problem solving syndromes.

The third chapter ‘Theoretical foundations of the SMILE learning environment’ discusses some educational philosophies, instructional approaches and theories that might contribute to designing of interactive learning environments.

Chapter 4 ‘Mental mapping approaches’ overviews some mapping techniques in the framework of their theoretical backgrounds, methods and software. The mapping software is analysed against a set of criteria formulated on the basis of the information derived from Chapter 2 and 3.

How the issues and tendencies in the theory and practice of problem solving, mental mapping and learning are transformed into design solutions in the SMILE Maker Tool can be found in the fifth chapter ‘Design and development of the SMILE Maker’.

Chapters 6, 7 and 8 are devoted to the evaluation of the SMILE Maker Tool. Chapter 6 presents the methodology of research. Chapter 7 reports on two expert focus group interviews and an experiment organised to get data about the effectiveness of the SMILE problem solving method. Chapter 8 discusses the administration of an experiment and a number of expert focus group interviews to find some evidence about the effectiveness of the SMILE Maker Tool as a problem solving and learning tool.

The ninth chapter 'Conclusions and Recommendation' summarizes the results of the study and draws some lines for future research. Figure. 1 visualises the structure of the study.

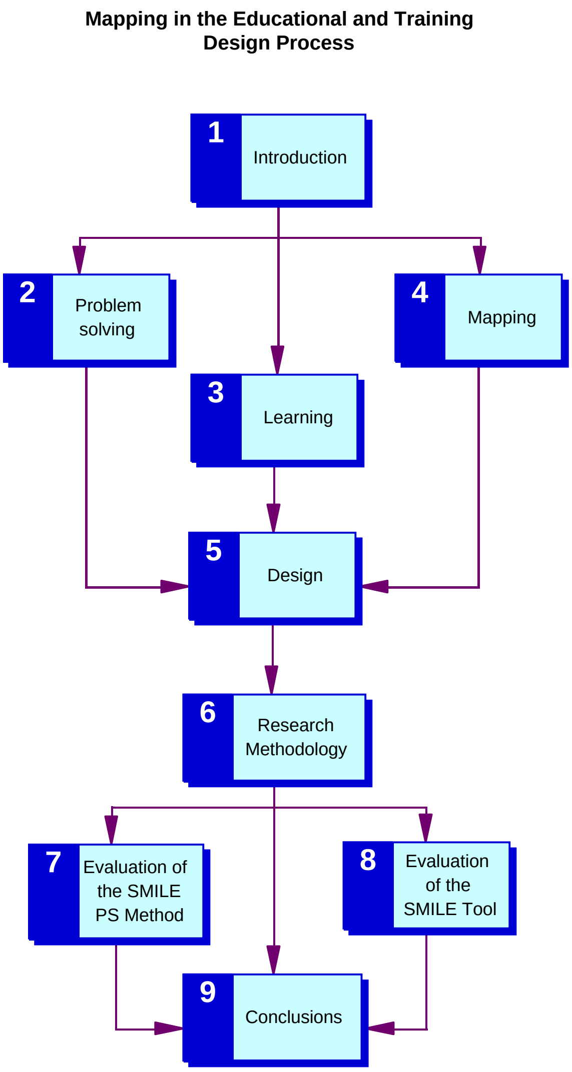


Figure 1. Overview of the chapters

Chapter 2. Problem solving theories and methodologies

Section 1.3 revealed some common tendencies and issues in the domains of educational design, engineering design and management consulting (Block, 2000; Hutchinson & Karsnitz, 1994; Schein, 1999; Tekinerdogan, 2000). One of the main issues was that design approaches need more operational and instrumental development such as defining the stages of the design process and promoting some concrete methods and techniques. Attention has gradually shifted from ‘hard’, formal and rational approaches towards more ‘soft’, informal and relational ones. Software engineering and management consulting have often used the classical and contemporary paradigms of problem solving in order to develop insights about improvement of the design paradigm. This has not been the case for educational and training design, with a few exceptions. In a recent article Dabbagh, Jonassen, Yueh and Samouilova (2000) have argued that instructional design should be considered as an ill-structured problem and that problem solving paradigm might provide valuable ideas for how to construct problem-based learning.

This chapter presents an overview of some problem solving theories and methodologies, positive and negative factors that influence problem solving, and problem solving techniques. These contributions could bring some insight for improving the existing theory and practice of the educational and training design. In general the chapter addresses the research question “In what ways could the problem solving paradigm contribute to the development of the SMILE problem solving method?”

The chapter consists of the following sections: 2.1 Definitions of problems and types of problems; 2.2 Overview of the classical problem solving paradigm; 2.3 Problem solving processes; 2.4 Negative conditions for problem solving; 2.5 Problem solving approaches; 2.6 Individual characteristics in problem solving; and 2.7. Problem solving methodologies.

Before starting the discussion of how a problem solving paradigm can contribute to designing a method that supports solving educational and training design problems it seems reasonable to begin with some definitions of what a problem is and to present some classifications of problem types.

2.1 Definitions of problems and types of problems

A problem occurs when an individual follows a goal, but is uncertain about action he or she should undertake (Newell & Simon, 1972). There is a considerable degree of consensus about what a ‘problem’ might be. Hicks (1993) referring to several popular definitions (Ackoff, 1978; Checkland, 1981; Eden, Jones, & Smits, 1983; Kepner & Tregoe, 1981; Nolan, 1989) found four substantial characteristics of a problem. They are as follows:

- We have *recognized* that there is a problem.
- We *do not know* how to resolve this problem.
- We *want* to resolve it.
- We *are able* to implement a solution when find it.

These four characteristics perhaps describe the difficulties people experience in a problem situation but do not say what a problem really is. Looking at the definitions that Hicks cited the common point is that a problem is an identification of the discrepancy between 'what is' and 'what should be', between the actual and desired state of affairs and finding ways of covering this gap. According to Van Gundy (1997) the following preconditions are necessary to begin a problem solving process:

- The existence of gap between what is and what should be
- An awareness that a gap exists
- An ability to measure the size of the gap
- The abilities and resources required to close the gap

Problems are usually described as varying on a continuum from well defined (well-structured) to ill defined. Van Gundy (1997) describes the taxonomy of problems as consisting of three types of problems classified on the extent to which they are structured. At one extreme are well-structured problems and at the another are ill-structured problems. Semi-structured problems take the middle position on this continuum. Well-structured situation are characterized by the availability of all the information needed to close the problem gap. This type of situation often can be solved applying algorithmic procedures. Ill-structured situations provide the problem solver with little or no information on the best way of developing a solution. Because no clear procedure exists for how to solve the problem, the problem solver should improvise and develop custom-made solutions. For semi-structured situations some information exists but it is not enough or there are some unclear points. Uncertainty exists about what is the current and what are the desired states of affairs, or what procedure to use in order to close the gap. Heuristics are reported to be the best for semi-structured situations. Heuristics are rules of thumb or guidelines that increase the likelihood of successful problem solving.

Kaufman (2001) reacts against the popular view in the literature that problems are presented to us by the outside world. This reflects the traditional view that humans are basically reactive and responding to ‘stimuli’ and ‘inputs’. Kaufman emphasizes that a problem exists as far as it is *perceived as* a problem by problem solver. The full understanding of problem solving requires a broader view about types of problems. Kaufman built a taxonomy of types of problems which consists of ‘presented problems’, ‘foreseen problems’, ‘constructed problems’ and ‘deceptive problems’. ‘Presented problems’ face an individual with difficulty to handle. Such a situation may be well structured (initial conditions, goal conditions and operations are clearly definable). At another pole are ill-structured problems where there are a lot of unknowns. Kaufman (2001) distinguishes between three different stimulus conditions that determine different aspects of ill-structured problems. These are novelty, complexity and ambiguity. There is also a class of problem called ‘foreseen problems’. An individual anticipates that a problem will occur if present trends continue. An interesting category in this taxonomy of types of problems is so called ‘constructed problems’. The initial conditions may be entirely satisfactory but the individual identifies a discrepancy between the actual state of affairs and future conditions. The problem may arise from a comparison with a future hypothetical state of affairs that could represent an improvement of the current situation. While in presented problem situations the inherent drive is ‘tension’ (clear or vague), in constructed problems the first step is to create ‘tension’ between the actual and desired situation. Kaufman underlies also the issue known as ‘deceptive problems’. This is when a situation looks familiar for applying a conventional problem solving approach, where a novel, non-traditional solution is what necessary.

Hicks (1993) also distinguishes between several types of problems. He firstly differentiates between complex and simple problems. This distinction is based on the structure of the problem. Secondly, there are well-defined and ill-defined problems. The separation is made on the criteria of whether problem solvers are confident about the direction of possible solutions. Thirdly, to make the things more complicated, Hicks adds to the types of problems classifications so called tame and wicked problems. He is mainly concerned with wicked problems. An educational and training design problem might be a wicked problem. Some of the characteristics of this type of problems are summarized as follows:

- Wicked problems do not have a definitive problem description.
- There is no certain way of knowing when the best solution is reached.
- Their possible solutions are not true or false but somewhere between good and bad.
- There is no immediate or ultimate way of testing the merit of a solution.

- They have an infinite number of possible solutions.
- The problem situation shows no precise indications as to what are/are not permissible ways of reaching a solution.
- Each problem is essentially unique.
- There are many ways of looking at the problem and each one suggests a ‘different’ direction in which we should perhaps look for a solution.
- Every wicked problem can be considered as a symptom of another problem.

Different types of problems require different approaches. A strategy for well-structured problems will not be relevant for ill-structured situations. The next section presents some of the classical approaches for problem solving which basically treat well-defined problems. Most of the research was done on puzzles where the right answer and means for reaching the goal are available explicitly.

2.2 The classical problem solving paradigm

The classical problem-solving paradigm has been dominated by research on well-defined problems such as Tour of Hanoi, Altar Window, The Nine-Dots, and The Two-string Problem. A comprehensive overview of existing approaches is given elsewhere (Eisenstadt, 1978; Eysenk & Keane, 1995; Hayes, 1978; Sternberg, 1994). In this section a short look will be taken at the most popular classical research approaches to problem solving. As was stated the attention of the current study in general is focused on ill-structured problems which typify educational and training design problems. However the early research within the classical problem solving paradigm provides valuable insights for developing a method for solving educational and training problems. The classical problem solving paradigm may also serve as a good basis for distinguishing the creative problem solving paradigm which is considered as appropriate for developing a method for soling educational problems.

The classical problem solving tradition distinguishes between behaviourist legacy, Gestalt psychology perspective and information-processing view on what might constitute problem solving (Eisenstadt, 1978). The Gestalt school of psychology extended their theory of perception to problem solving behaviour. This interprets problem solving as organizing, processing and restructuring of perception. The theory was mainly interested in the substantial role of insight in problem solving. Insight is defined as a sudden restructuring of the problem situation as understood. Restructuring means building up a new configuration of the elements in the problem situation. In order to do that the relationships between components of problem situation as whole have to be understood. Designing a solution of a problem means changing the way in which one sees a problem situation (Wertheimer, 1987). The Gestalt theory of problem solving can be summarized as follows (Wertheimer, 1987):

- Problem solving behaviour is both reproductive and productive
- Reproductive problem solving involves the re-use of previous experience and can inhibit problem solving (the negative syndromes of problem solving set and functional fixedness)
- Productive problem solving is characterized by the sudden restructuring of a problem situation into a new configuration or 'gestalt'.

According to Gestalt theory, problem solving is more than reproduction of learned responses. It involves insight and restructuring. Problem solving that relies mostly on past experience often lead to failure.

'Problem solving as learning' is the position of the behaviourists. In the problem solving situation we try to approach the problem with what we already have learned in our previous experience. If the approach does not work then we try another one until a satisfactory answer arrives. A series of such trial-and-error discoveries followed by rewards would lead to improved performance. This can be view as an implication of the 'law of effect', a response followed by a reward become associated with the stimulus situation to which the response was made. Problem solving behaviour is based on such stimulus-response associations. A given stimulus could have several responses associated with it or a given response could be triggered by different stimulus (Eisenstadt, 1978).

'Learning as problem solving' is the position of the classical cognitive approach. Learning comes about when a person encounters difficulties in a problem situation and has to modify or even to change an internal problem solving representation and existing cognitive structure (Eysenk & Keane, 1995). This concept of learning could be viewed as a form of problem solving behaviour.

A major breakthrough in the study of problem solving occurred when Newell and Simon (1972) developed their theory of problem solving. The theory is based on the metaphor that human information processing is like a computer program. According to the theory, the process of problem solving can be expressed as a set of rules for manipulating symbols. A computer program that behaves like a real human being is analogous of human problem solving.

One of the practical principles formulated by Newell and Simon (1972) is that problem solving essentially is searching solution paths through a problem space. The first step in problem solving is to determine the problem space. The structure of the problem space can be characterized as a set of states, beginning from an initial state, involving many intermediate states and ending with a goal state. The next step is to find a strategy to move from one state to another. People use their knowledge and various heuristics methods to search through the problem space and to find a path from the initial state to the goal state.

The classical problem solving paradigm gained credit with the efforts to show what really happens during problem solving. Researchers adherent to this theoretical perspective conducted many studies and collected some valuable experimental data. The results of these investigations were used extensively for explaining some of the effects of problem solving that occur in non-laboratory settings. Sometimes researchers that belong to other paradigms present the results of their studies as distinguishing themselves from the classical problem solving paradigm. However as it was stated at the beginning of this section the classical problem solving paradigm was mainly concerned with well-defined problems and content-independent strategies. It was not applied to investigate ill-structured real life problems.

The concept of ‘problem space’ (Newel & Simon, 1972) developed in the framework of information processing theory became attractive for the current study because it suggests a metaphor that could be expressed by drawing a map where all important factors are connected in a network. Another issue reported in the framework of information processing theory and adopted in the current study were the limitations of working memory and the constraints of the speed of storing in and retrieving information from long term memory. The development of a method for solving design problems that is the subject of current research tries to overcome working memory limitations. Another interesting issue defined in the framework of the classical problem solving paradigm persistently appearing in the later research on problem solving is the relationship between problem solving and learning. The classical problem-solving paradigm was not interested very much in the problem solving process – an issue that is increasingly attracting the attention of the researchers. The following section provides some information about the stages and the structure of the problem solving process.

2.3 Problem solving process

It might be stated that there is an agreement in the literature about problem solving stages. Some authors prefer to identify a few main phases and then to describe some more concrete stages within each of the main phases. For example, Simon (1977) classifies problem solving stages as intelligence, design and choice. The first phase of intelligence includes identifying the problem. Design involves inventing, developing and analysing possible courses of actions. The third phase is about selection of a particular course of action and evaluation of results of that action. Based on the model of Simon (1977), Van Gundy (1997) proposes an extended model for problem solving. Each stage in Van Gundy’s model is divided into the substages of intelligence, design, and choice. The model begins when a problem situation is initiated by environmental stimuli. In the intelligence stage of the model, the initial problem definition is analysed and a search begins for collecting relevant information. The design substage is then initiated in which alternative problem definitions are generated. In the choice sub-stage a working problem definition has to be selected. The final deliverable of this substage is a problem statement that is the beginning of the intelligence substage of the design problem solving phase. The main goal of this intelligence substage is to search for ready-made solutions. If solutions are not available, possible creative problem solving techniques are generated in the design substage and in the choice sub-stage some of them are selected. The final deliverables of the design phase are the solutions generated. The objective of the intelligence substage of the choice phase is to search for information that can be used to evaluate possible solutions. Possible solution consequences are then produced in the design sub-stage followed by the selection of a tentative solution in the choice sub-stage. If no new information is received, the solution is implemented and its success evaluated through the feedback loop to the environmental stimuli. The positive features of the extended model of Van Gundy can be summarized as follows:

- The idea that the main phases of the problem solving process should include substages with both divergent and convergent activities in mind.
- The clear definition of the final deliverables of each substage and phase. The deliverables are used as a starting point for the next stage or phase.
- The idea of recycling and looping in the process according to received information.

However the concrete realization of this idea of stages and substages in the extended model of problem solving is somewhat confusing. A matrix is applied where each of the phases of problem solving such as intelligence, design and choice includes the substages of intelligence, design and choice. The presented model is very short of information about implementation. The model just jumps to implementation without a clear hint of what it is – phase or substage. Apparently the model recognizes the importance of implementation but it does not say how it is linked with the core concepts of intelligence, design and choice. In another publication Van Gundy (1992) proposed another classification. It consists of the following components: objective finding, fact finding, problem finding, idea finding, solution finding, and acceptance finding. Summarizing the research on the problem solving process, Kaufman (2001) distinguishes three phases of problem solving: identification of the problem, development of solutions and selection of solution. De Bono (1990) developed a classification, which is similar to the already reported of Van Gundy (1992) and Kaufman (2001) although he called the problem solving stages ‘types of thinking’’. They are as follows:

- Exploring. Looking around, increasing knowledge and awareness of the problem. Make a better map of it.
- Seeking. Design a new creative idea.
- Choosing. Select among alternatives generated.
- Organizing. Put pieces together in the most effective way.
- Checking. React to what has been done. Judge it.

Hicks (1993) elaborated on the existing classification of problem solving processes adding some psychological conditions at the beginning of the process and defining types of data for collecting. The process of problem solving consists of the following stages:

- The 'Mess'. We start with the feeling that a problem exists. Psychologically it may be described by feelings of doubts and toughness. We are intimidated by the complexity of situation and anxious about our competencies.
- Data gathering. We start to collect different types of data such as:
  - Objective data –who, what, where, when, why, and how of the situation
  - Subjective data – opinions, attitudes, feelings and beliefs
  - Details of any constraints that exist – legal, financial, time
- Defining the problem. There may be several valid ways of looking at the problem that all need to be considered.
- Generating ideas. At this stage as many as possible ideas should be generated. Some special techniques for idea generation might take place here. No evaluation or judgment is necessary here because this prevents the production of unconventional ideas.
- Solution finding. The objective here is the selection of the most promising candidates among ideas that have been generated. The ideas might be checked against a set of criteria.
- Gaining acceptance. No matter how elegant and brilliant the solution it does not count very much if appropriate steps are not undertaken to sell it, to gain acceptance and elicit commitment to implementation of the solution.

This section brought the idea of the importance of defining the framework of problem solving that may consist of a number of phases or stages. Each of them has a particular purpose to attain. The sequence of stages with specific objectives makes the process of problem solving systematic. However the concept of the problem solving process should not suggest linearity. It is natural to think of problem solving as a movement back and forth with possible loops between stages. A method that supports solving design problems should implement the idea of problem soling process including some stages. Most of the classifications reported following stages: analysing situation, problem defining, information collecting, generating ideas, selecting ideas and ideas implementing. Analysing design situation, defining problem and collecting information could be considered as one stage because these activities are related to each other very much.

The efforts to define what may constitute the most effective structure of the process of problem solving are triggered by the need to deal with a number of negative conditions inhibiting problem solving. The comprehensiveness of the problem solving process and a well-dosed specific support may lead to avoiding the effects caused by these negative syndromes. Knowing what they are would help in planning some measures to cope with them.

2.4 Negative conditions for problem solving

The theory and practice of problem solving have identified a number of factors that have an impediment effect on the effectiveness of the problem solving process. Kaufman (2001) defines the following conditions inhibiting problem solving:

- *Cognitive economy*. This is a rational strategy developed to deal with the issue of cognitive limitations of the human information processing system. Cognitive economy might keep variation and changes to a minimum. It might lead to rigidity, stereotyping and dysfunctional resistance to change in situations that requires restructuring and changing of the established patterns.
- ‘*Einstellung’ effect*. The ‘Einstellung’ effect marks the behaviour of a problem solver who has discovered the strategy that initially functions well in solving a certain tasks, but later on inhibits designing new and simpler solutions to similar, but not exactly the same problems.
- *Functional fixedness*. Functional fixedness reflects the phenomena of an impediment effect of past experience on problem solving. People are fixated in a frame or reference developed from previous experience of solving particular problems. The functional fixedness effect was discovered by the Gestalt psychologists.
- *Hidden assumptions*. Fixation in problem solving might be caused by certain assumptions of how a problem has to be solved which limits the search for productive solutions.
- *Confirmation bias*. People tend to seek confirming evidence and to avoid disconfirmation or discard disconfirming evidence when presented.

- *Conservatism in hypothesis testing*. People are reluctant to reduce their confidence in a decision following disconfirmation. Thus the probability to resist changing and restructuring in problem solving is high.

Hicks (1993) identified some perceptual, cultural, emotional, organizational, intellectual and expressive blocks for problem solving. For the current study a subject of interest are the perceptual and emotional blocks. The perceptual blocks are stereotyping, ddifficulties in isolating the problem, tunnel vision, inability to perceive the problem situation from various viewpoints, and saturation. The 'emotional blocks' are the second type of blocks that could have a detrimental effect on problem solving. They are obsessive desire for security and order, fear of making mistakes, unwillingness to take a risk, lack of motivation, Inability to reflect on ideas, trying to solve problems too quickly, and a preference for judgment.

De Bono (1990) adds to the list some more negative conditions for problem solving in the terms of his theory of the human mind as a self-organizing information system. Self-organizing systems are patterning systems. A patterning system is very useful but it also has some disadvantages. There is always a dominant pattern that determines the way one perceives and organizes information and not even be aware of the existence of other opportunities. As information proceeds along a one pattern pathway, the other patterns are completely ignored. A person looking at a situation in one way may be completely unable to see it from an alternative point of view. One of the issues is that following an established pattern for the people is impossible to ignore a satisfactory view of things to find a better one. It is easier to establish a new pattern than to cut across the old one. It is quite easy to combine two patterns to form a larger one than to combine bits of established patterns. Patterning systems are very open to mistakes. If two completely different situations are presented at the beginning in the same way, then it is very easy to apply the wrong pattern. In practice people tend to identify and apply a pattern rather early without investigating the problem situation for possible alternatives. If they cannot easily identify the needed pattern, they may pick the 'nearest' which might be inappropriate.

The sequence of arrival of information is very important characteristic of a patterning system. The arrangement at any moment can never make the best use of available information. There is always a need to try to restructure an idea in order to get better one. Restructuring means putting together in different way information that is already available.

Knowing what are the negative conditions for problem solving is an important step in designing appropriate problem solving approaches. The next section proposes an overview of existing problem solving methodologies and approaches. They are based on different principles and offer different strategies for overcoming the cognitive affective blocks in solving design problems.

2.5 Problem solving approaches

Basically two main approaches to deal with the number of negative conditions for problem solving could be identified. They are ‘reducing complexity approaches’ (Section 2.5.1) versus ‘managing complexity approaches’ (Section 2.5.2).

2.5.1 ‘Reducing complexity’ approaches

‘Reducing complexity’ approaches are based on Bounded Rationality Theory (Simon, 1972). The theory assumes that people while seeking for the best solution usually settle for much less because the solutions they are looking for typically demand greater information processing capabilities than they possess. People search for a sort of bounded (limited) rationality in solutions based on the limitations of the human processing system. Many of the bottlenecks observed in cognitive tasks may be traced back to basic limitations in short-term memory. According to the famous rule ‘7±2’ our mind can handle up to this number unrelated information units (Miller, 1956 cited in Benjafield, 1996). To increase memory capacity people have to organize information in high order packages called ‘chunks of information’. At each step the problem solver has to develop a mental model of the situation. The complexity of mental models and the existence of alternative models exhaust the capacities of working memory.

Another bottleneck in human cognitive system is the time which is necessary to proceed from short- to long term memory (Kaufman 2001). At the same time most problems contain many paths to the goal. According to theory of bounded rationality, to deal with this issue an individual has to construct rather simplified models of reality. He or she will follow a strategy of satisfying directed by the value what is ‘good enough’. More precisely the problem solver is expected to select the first alternative he or she meets that cover some minimum standards of satisfaction.

The bounded rationality model attempts to describe the problem solving process in terms of three mechanisms:

- *Sequential attention to alternative solutions*. People examine possible solution to a problem – one at a time. They identify and evaluate various alternatives individually. If the first solution fails to work or is evaluated as unworkable, it is discarded, and another solution is considered. When an acceptable solution (not necessary the best) is found the search behaviour is discontinued.

- *Use of heuristics*. A heuristic is a rule that guides the search for alternatives. It has a high probability for producing satisfactory solutions. Problem solvers use heuristics to reduce large problems to manageable propositions so solutions can be made rapidly. Heuristics should help a problem owner to simplify the problem by showing the most likely solution paths.
- *Satisficing*. An alternative is satisfactory if it satisfies a set of criteria that describes minimally satisfactory conditions.

Assuming these basic mechanisms, the bounded rationality model of problem solving consists of the following guidelines:

- Set the goal or define the problem to be solved.
- Establish an appropriate level of aspiration, or criteria level.
- Employ heuristics to narrow problem space to a single promising alternative.
- If no feasible alternative is identify, lower the level of aspiration and begin the search for a new alternative solution.
- After identifying a feasible alternative, evaluate it to determine its acceptability.
- If this alternative is not acceptable, initiate the search for a new alternative solution.
- If the alternative is acceptable, implement the solution.
- Following implementation, evaluate the effort with which the goal was (was not) attained and raise or lower the level of aspiration accordingly for a future use of this type.

Inspired by the theory of bounded rationality, research on problem solving has been heavily focused on using heuristics for the purposes of simplifying problems and confining search activity to the most promising solution paths. Heuristics are typically rules-of thumb or shortcuts that allow problem solvers to arrive at a solution efficiently. There are two types of heuristics of simplification: proximity methods and planning. Proximity methods are ‘The hot and cold strategy’, ‘Hill climbing’, and ‘Means-end analysis’. In ‘The hot and cold strategy problem solver looks for ‘hot’ signals to move closer to and ‘cold’ signs to move away from a search route. ‘Hill climbing’ technique requires taking one step at a time and evaluation its consequences. According to ‘Means-end’ analysis search is guided by attempts to reduce the difference between the initial state and the goal state selecting different means of approaching the goal. Sub-goal strategy is a part of this heuristic. Rather than trying to solve the problem as given it seem to be a good idea to subdivide it into several smaller and probably well structured sub-problems. The planning methods are ‘Planning by modeling’, ‘Planning by analogy', and 'Planning by abstraction'. 'Planning by modeling' requires constructing of a simplified model of the situation to avoid going in wrong direction and making errors. Plans for solving a problem can be designed by analogy where the solution of a problem is used as a basis for solving another similar problem. 'Planning by abstraction' means that the solution of a simpler problem is used for solving more complex problem.

The problem solving strategies analysed so far are purposed to simplify problems. The main concern is reducing complex problem spaces and selection of appropriate heuristics for this purpose. The heuristics of simplification have developed under the theoretical background of bounded rationality theory. These techniques are legitimate in well-structured or semi-structured situations where the ends and means are known but they are irrelevant in ill-structured situation where real creative solutions are needed (Schön, 1996). According to Schön, The Bounded Rationality Theory of Simon (1972) does not have the necessary means to deal with real-life problem situations characterized by complexity, uncertainty, instability, uniqueness, and value conflict. The Bounded Rationality Theory assumes that problems are givens and the ends and means are clear. Schön claims that the issue is problem setting and the real challenge is constructing problem out of a problem situation, defining ends and finding appropriate means for achieving them. In most of the ill-structured problems there is a pluralism of conflicting approaches. The task of problem solver is to design the right combination of their components. The real concern in an ill-structured situation is that solutions are blocked by searching in too narrow a problem space. The problem solver has to enlarge the space and see and explore new possibilities in order to get satisfactory solution. There is a tendency to stick too closely to an established pattern of procedures when the problem requires developing new patterns. The problem is rather of constructing a new problem solving space and to search for new alternatives.

Schön proposes an epistemology of practice called 'reflection-in-action' that is supposed to explain how high profile experts deal with an ill-structured situation. Reflection-in-action means "we can think about doing something while doing it" (Schön, 1996, p. 54). When experts reflect in action they see the problem situation as something in their repertoire. They catch either similarities or differences in the cases tacitly. It is a merit of Schön to show the ineffectiveness and inefficiency of traditional problem solving approaches to manage the complexity of ill-structured situations. However the approach he suggested lacks instrumental value. Schön did not describe in concrete procedural terms what it means to make sense of uncertainty, perform artistically, set problems, seeing-as and doing-as problem situations, choose among competing professional paradigms, and design as reflective conversation with problem situation. The approach proposed by Schön needs further elaboration and development of new sort of principles, techniques and heuristics.

Kaufman (2001) proposes heuristics that should be applied to answer adequately the sort of problems that requiring creative solutions. These heuristics also are called heuristics of variation and are as follows:

- *Adding stimuli*. New stimuli can be added to expand the problem solving representation or to present the problem in different terms. Metaphors and analogies are other ways of adding stimuli.
- *Removing stimuli*. Irrelevant stimuli could lead the problem solver to select a wrong pattern or search non-adequate problem space. The problem solver should be able to recognize irrelevant from adequate stimuli.
- *Rearranging stimuli*. Using this technique might restructure the problem space provoking the generation of unconventional solution. The spatial arrangement of the stimuli when moving around is also important to change the configuration and to see the problem in different way.
- *Visualizing stimuli*. Reports on inventions and scientific discoveries suggest that inventors were often visualizing complex situations when their flash of insight took place. Imagery gives access to a set of cognitive processes of a perceptual kind such as anticipations and comparisons. This may be useful in ill-structured environments where computational operations in the sense of rule governed inferences are difficult or impossible to perform.

Some of the heuristics of variation such as ‘adding stimuli’ and ‘removing stimuli’ could be realized through some creative problem solving techniques (metaphors and analogies). Others such as ‘rearranging stimuli’ and ‘visualizing stimuli’ could be realized by mapping techniques. The combination between mapping and problem solving in applying all these heuristics seems to be a stronger factor than the single use of mapping or creative problem solving. The heuristic of variations can be defined as a set of principles for ‘managing complexity approaches’. However they are very general guidelines giving a direction for searching a solution but they are not attached to concrete techniques for how to design a solution to an ill-structured problem. The next section will introduce another problem solving paradigm encompassing ‘managing complexity approaches’. ‘Managing complexity approaches’ are based on the theories of creativity and creative problem solving principles, techniques and methodologies.

2.5.2 ‘Managing complexity approaches’

‘Managing complexity’ approaches are based on some creative principles and apply some creative problem solving techniques. Creativity always has been considered as a part of the design process. Creativity and problem solving are intimately linked. The more the person actively explores the problem space prior to producing a solution, the more creative the result is like to be. There is a tendency among researchers on creativity to interpret this phenomenon not only in the terms of product but also in the terms of process (Hicks, 1993). Wherever and however creativity is manifested, it is commonly believed that the same mental processes have been used to produced it. Emphasizing the process variables of creativity, Hicks defines the creativity as the ability to make connections between seemingly irrelevant and unrelated objects, ideas, information and events.

The next section 2.5.2.1 'Theory of creativity' introduces to some of the classical and the most influential theories of creativity such as Guilford's divergent-convergent production theory, Torrance's divergent theory, associative theory of creative thinking of Mednick, Selector-Integrator Mechanism of Maier, Simonton's Chance-Configuration theory, and De Bono's lateral thinking theory.

2.5.2.1 Theories of creativity

There are a number of theories that try to explain the mechanisms of creative thinking. Many definitions of creativity apply the concepts of divergent thinking and creativity interchangeably. Divergent production is one of the most popular concepts of creativity. Divergent production is part of Guilford's structure-of-intellect model (1967) where cognition is organized along three dimensions: operations, content and product. These are combined to produce 120 different mental abilities. Guilford and his associates designed a test to measure many of them and to validate their concepts via factor analysis.

Guilford identified four main categories in divergent production:

- Fluency - an ability to produce a large number of ideas.
- Flexibility – an ability to produce a wide variety of ideas.
- Originality – an ability to produce unusual ideas
- Elaboration – an ability to develop ideas and to produce many details to 'flesh out' an idea.

Torrance's (1988) theory of creativity is also a divergent type theory. It is considered as the most influential divergent thinking theory nowadays. The popularity of the theory is based on the creativity tests, which Torrance designed and administered. Torrance' tests provide separate fluency, flexibility, originality and elaboration scores and overall creativity index.

The associative theory of creative thinking of Mednick (1962) was inspirited by the French mathematician Poincaré. According to him to create means making new combinations of associative elements which are useful. The most interesting are remote associations. Mednick claims that any condition that increases the likelihood of bringing together the associative elements needed for a creative solution will increase the probability of that creative solution. He proposes three ways in which it may happen: ‘serendipity’ – any chance contiguity of associative elements in the environment that leads one to creative insight; similarity - similarity of associative elements or of stimuli that evoke those elements; and mediation of common element, typically through the use of symbols. Mednick identified some factors that could account for some individual differences in producing creative solutions. Domain-specific knowledge is essential. Some people produce great numbers of associations, thus increasing the likelihood of creative solutions. Differences in cognitive or personal style may influence the probability of reaching creative solutions. The selection of the creative combination from the many possible associations is central to the theory of creativity. The most important factor Mednick proposed was associative hierarchy referring to how individual associations are organized. Less creative people have steep associative hierarchy. More creative people have flat associative hierarchy.

According to the theory of *Selector-Integrator Mechanism* (Benjafield, 1996; Maier, 1970;) people have in their disposal a set of abilities. This is called their behavioural repertoire and constitutes all the things they are capable of doing. The elements in the behavioural repertoire may be relatively innate, or they may be relatively learned. In any situation the task of the mind is to select the appropriate behaviours from the behavioural repertoire and then integrate them into a pattern that constitutes an adequate response to the situation. People are in part selectors of their own behaviour and are also in part organizers of their own experience. Performance on a specific occasion may be a unique mix of innate and acquired elements. On one level (behavioural repertoire) the organism is at any point in time quite limited. On another level (selection and integration of elements) the organism may be quite flexible. From Maier’s viewpoint, it is the way that behavioural elements are selected and integrated (selective-integrator mechanism) that distinguishes a more creative person from a less creative person. The creative person does not simply repeat elements of the behavioural repertoire in isolation from one another, but it is able to recombine elements in novel ways to suit changing circumstances. An important criterion of creativity is the extent to which people are able to take the context into account when they selecting and integrating the behaviour they perform in a given situation.

Simonton’s *Chance-Configuration theory* (1993) of creativity is a sort of elaboration on the approach advanced by Campbell (1960, cited in Simonton, 1993). Campbell applied Darwinian evolutionary theory to the process of knowledge acquisition. According to him there are two key aspects to the evolutionary process. One of these aspects is blind variation, which refers to a process whereby alternatives are explored without knowing in advance which alternative will have the desired consequences. An example of blind variation is pure trial and error approach to a problem. Creative thinking involves a blind variation on a symbolic level. The person can imagine various alternative courses of action as well as the selection criteria for an appropriate action. The variation is blind when a person has no idea what the answer will be and any idea is possible candidate. There is no restriction on the ideas this process may generate. Most of the ideas will be of little or no value. However eventually the process of generating alternative ideas may result in a hit. The key mechanism of creative thinking is serendipity – accidental discovery. Alternatives that meet the selection criteria are retained for future use in similar context. Simonton (1993) stated three core propositions:

The productivity of ideas is distributed in the terms of random permutation process. Productive people have a greater number of mental elements. The more mental elements available to a person, the more combinations of these elements are possible. As the number of mental element increases, the number of permutations of these elements increases at much faster rate.

De Bono (1990) claims that to foster creativity of people special techniques have to be developed. These techniques are part of the lateral thinking – concept introduced by him. The need for lateral thinking arise from the way the mind behaves as a patterning system which requires discontinuity in order to change patterns and bring them up to date. Lateral thinking is concerned with change - escaping from old ideas and the generation of new ones.

Michalko (1998) analysed the thinking strategies of so called creative giants from the sciences, arts and industry. The list includes the names of Einstein, Darwin, Leonardo da Vinci, Freud, Picasso, Edison, Mozart, Pasteur, Galileo, Bohr, Bell, Disney, Newton, and Russell among others. Michalko derived the following creative principles:

- *Knowing how to see*. This is about finding new perspectives to the problem that no one else has taken yet.
- *Make your thought visible*. The parallel language of maps, diagrams, and graphs gives flexibility to display information in different way. Most of the geniuses had had a very visual mind.
- *Thinking fluently*. A distinguishing characteristic of genius is enormous productivity. After the quantity of work came quality.
- *Making novel combinations*. Genius constantly combining and recombining ideas, images, and thoughts into different configurations in their conscious and unconscious minds.

- *Connecting unconnected*. This ability to force relationships between unconnected things enables genius to see things to which others are blind.
- *Looking at the other sides*. This is an ability to tolerate ambivalence between opposite or incompatible subjects.
- *Looking in other worlds*. To think metaphorically, to have a capacity to perceive resemblance between two separate domains is considered as special gift.
- *Finding what you are not looking for*. Sometimes people attempting to do something fail but they end up with something else. The reasonable question might be 'why this happened?' However the most important is to take the benefit from the case considering it as a creative incident.

The rational assumptions of the theories of creativity of Guilford (1967), Mednick (1962), Maier (1970), Simonton (1993), and Michalko, (1998) could be operationalised as a set of creative problem solving techniques, which may add a real value to the process of solving design problems. They are the subjects of the following section 2.5.2.1.2 Creative problem solving techniques.

2.5.2.2 Creative problem solving techniques

Van Gundy (1992) collected a number of some well known and popular creative problem solving techniques such as: attribute listing, problem reversal, morphological analysis, analogies, metaphors, free association, brainwriting, listing, lateral thinking techniques and tools, weighting systems, potential problem analysis, forced relationship, and force-field analysis. He formulated the benefits of using creative problem solving techniques as follows:

- *Uncertainty reduction*. A major obstacle of solving ill-structured problems is the initial uncertainty experiences about problem dimensions and likely outcomes. The existence of the problem might be recognized but its scope, number of dimensions and how they fit together may be totally unknown. Because problem-solving techniques emphasize on collecting information, most of the creative problem solving techniques might decrease the uncertainty by increasing the amount of the relevant information about a problem. Thus the most information about a problem and how it can be solved is known, the less will be the uncertainty about eventual resolution of the problem.
- *Increased alternatives*. Based upon simple probability estimation, a large number of alternatives will be more likely to produce feasible solutions than the first one or two that happen to emerge. If only very few alternatives are considered the best possible solution might be omitted.

- *Decreased revisions*. Because problem-solving techniques support problem analysis and idea generation, they may decrease the likelihood for revisions of solutions. The need for revising a solution is due usually to inadequate problem analysis and ineffective generation of alternative solutions from which to choose.
- *Efficient utilization of individuals*. Creative problem solving techniques can help to improve human resources efficiency by providing new ways of solving problems. People use only part of their potential for solving problems. This is valid especially for people that are involved in routine tasks.

De Bono (1992) proposes a number of 'tools' that implement the lateral thinking principles he promoted. These are 'Consider All Factors', 'Alternatives, Possibilities, Choices', 'Other People View', 'Consequence and Sequel', 'Plus, Minus, Interesting', 'Aims, Goals and Objectives', and 'First Important Priorities'.

It is a problem solver who applies creative problem solving techniques. Personal characteristics might influence the way of applying the techniques. People have particular preferences as to how they approach and proceed through a problem. The following section presents some classification of problem solving styles and discusses how they may affect problem solving.

2.6 Individual characteristics and problem solving

There are some personal characteristics such as abilities, knowledge and problem solving styles that might affect the effectiveness of problem solving. Section 2.6.1 discusses creative abilities. Section 2.6.2 presents knowledge as a factor for creativity. Section 2.6.3 reports on the effect of problem solving styles on problem solving.

2.6.1 Creative abilities

Guilford (1967) verified empirically seven distinct creative abilities: sensitivity to problems, fluency of thinking, flexibility of thinking, originality of thinking, ability to analyse information, ability to synthesize information, and ability to 'redefine' things. In addition, he identified two types of productive thinking – divergent thinking and convergent thinking.

Lubart (1994) classifies problem solving abilities into two categories: basic and high order intellectual abilities. Divergent thinking and insights are basic creative problem solving abilities. *Insight* is defined as a cognitive transition that involves restructuring the nature of a problem or the elements that contribute to a problem's solution. Subjective insight seems to appear suddenly and to evoke an 'aha' experience. Insight may include the following three characteristics: noticing relevant new information, comparing information and finding relevant connections, and combining information in a problem relevant fashion. Often key information already exists but people are not able to see its value. Storing information in long-term memory helps a person to find problem relevant information when new information is processed through regular cognitive channels. Another source for insightful ideas is using analogies or metaphors. The third insight ability on which researchers have focused is the combination of information. This type of ability can be operationalised with the ability to make remote associations and abilities for seeing a particular idea within different frames of references or to combine two or more ideas habitually conceived as unrelated.

As a strategy people may vary about whether and how they use *divergent thinking* or not. Some of them produce many and different types of ideas. Some generate very few and not diverse ideas. The mechanism by which divergent thinking operates may involve multiple memory searches in which the problem probe is modified each time.

The high order problem solving abilities are problem finding, problem representation, strategy selection, and effective evaluation.

Problem finding means detecting a gap in the current state of knowledge, a need for a new product, or a deficiency with current procedures in a domain. Many problems that offer the possibilities for creative solutions are ill-defined problems. An adequate problem definition requires exploration of problem space in order to uncover the substantial relationship between the components of the problem under study. Visualization through mapping could contribute essentially in identifying and representing the relationships between the factors in a problem situation.

Closely related to problem finding is the ability to select an appropriate *problem representation*. The representation can affect memory load and the extent to which everyday knowledge can be linked to the problem. There are experimental reports (Eysenk & Keane, 1995) pointing out that visual imagery can support creative problem solving. Visual thinking in its various formats can be useful for creative problem solving because images are easily altered, can represent multiple aspects of a problem, can be manipulated rapidly, and often do not have well-established boundaries for verbal representations. Mental maps are excellent candidates for supporting this function because of capability to combine visual and verbal representations.

The ability to employ heuristic approach is a beneficial *strategy* for creative problem solving. A heuristic search allows the problem solver to focus on potential solution paths and to ignore a wide array of fruitless options. It also has been suggested that knowing when to use divergent and convergent thinking is strategically important. Alternating between these modes of thinking may be an optional strategy for creativity. Effective *evaluation and selection* of the most appropriate ideas among already generated is the final high-level ability that facilitates creative problem solving.

Apart from abilities, knowledge plays as well as an important role in problem solving. A generalisation is that several years of knowledge acquisition are necessary before creative masterworks tend to be produced (Eysenk & Keane, 1995).

2.6.2 Knowledge

Knowledge is important for creativity in the following ways:

- Without knowledge is difficult to recognize problems or to understand the nature of these problems.
- Knowledge prevents a person from simply rediscovering old ideas.
- Knowledge helps a person to know about the current ideas, to move away from these ideas and to introduce novelty.
- Knowledge helps a person to notice and make use of chance occurrences as a source of ideas.
- Knowledge helps a person to concentrate his or her cognitive resources on the processing of new ideas because the basics of a task are already known.

However, sometimes knowledge is an impeding factor for creativity. It comes at the expense of flexibility. The effects of functional fixedness and problem set are an example. Past experience and previously learned strategies could negatively affect problem solving.

Problem solving styles are the next personal construct with an important role in problem solving. They exist at the interface between cognition and personality traits. As an integrated construct problem solving styles include abilities, cognitive styles, and some personality characteristics.

2.6.3 Problem solving styles

Problem solving styles are the ways people prefer to apply their intellectual abilities and knowledge to a problem. Lubart (1994) classifies problem solving styles according to a global-local dimension. People with a local problem solving style like to work on narrow, detailed aspects of a problem. Global problem solving stylers prefer to work on broad, general level of a problem. Creative solutions often involve seeing the big picture first, and hence a global style is hypothesized to be important. However in some of the later phases of creative work, attention to detail becomes necessary for completing the task.

Hellriegel, Slocum, Woodman (1992) based the definition and description of problem solving styles on the classification of Jung (1923, cited in Hellriegel, Slocum & Woodman, 1992). Two psychological functions that are involved in information gathering were identified (sensation and intuition) and two functions supporting evaluation were discovered (thinking and feeling). A person usually prefers one way of gathering data and one way of evaluating that data. A person may use a secondary method for the fine-tuning basic approach. Individuals collect information either by sensation or intuition but not usually simultaneously. The same is valid for thinking and feeling in the evaluation of information. Based on the functions described, four types of persons are identified: sensation-type, intuitive-type, feeling-type, and thinking-type.

In terms of problem solving styles the sensation-type person tends to:

- Dislike new problems, unless there are standard ways to solve them.
- Enjoy using skills already acquired more than learning new ones.
- Work steadily with a realistic idea of how long a task will take.
- Work through a task or problem to a conclusion.
- Be impatient when details get complicated.
- Distrust creative inspiration.

The intuitive-type of person tends to:

- Keep the total picture or overall problem continually in mind as problem solving proceeds.
- Show tendency, willingness and openness to continually explore possibilities.
- Rely on hunches and non-verbal cues.
- Simultaneously consider a variety of alternatives and options and quickly discard those judged unworkable.
- Jump around or back and forth among the usual sequence of the steps in problem solving process and may suddenly want to reassess whether the ‘real’ problem has even been identified.

The feeling-type of person tends to:

- Enjoy pleasing people even in ways that other people consider as unimportant.
- Dislike dealing with problems that requires telling other people something unpleasant.

- Be responsive to other people's problems.
- Emphasize the human aspect in dealing with problems and view causes of inefficiency and ineffectiveness as interpersonal human problems.

The thinking-type of person tends to:

- Make a plan and look for a method to solve a problem.
- Be extremely conscious of and concern with the approach to a problem.
- Define carefully the specific constrains in a problem.
- Proceed by increasingly refining an analysis.
- Search for and obtain additional information in an orderly manner.

As a result of this analysis four problem solving styles were defined: Sensation-Thinkers, Intuitive-Thinkers, Sensation-Feelers and Intuitive-Feelers.

Based also on the typology of Jung, Myers and Briggs (1993) have developed a theory and Type Indicator (MBTI) for identifying and measuring different personality types. The theory tries to explain personality differences as different patterns of behaviour. The theory is based on the assumption that people are born with preferences. Myers-Briggs identified four pair of opposite preferences. People tend to favour one pole over another and use it the most of the time because it comes more easily and with less effort and energy. The four pairs of opposite preferences are as follows:

- Extraverting (E) v/s Intraverting (I) – where we focus our attention and what energizes us.
- Sensing (S) v/s iNtuiting (N) – how we prefer to take in information.
- Thinking (T) v/s Feeling (F) – how we evaluate information and make decisions.
- Judging (J) v/s Perceiving (P) – refers to one's lifestyle orientation.

People have preferences for one of the options of the each pairs. For example a person might have Introverting, Intuiting, Thinking and Judging preferences – thus an IITJ pattern. All together there are sixteen types of personalities. The Myers-Briggs personality classification is being referred as one the most popular classifications of problem solving styles. However it is disputable whether the personal types might be considered as a problem solving styles.

Keirsey and Bates (1998) saw within the 16 personality types of Myers-Briggs some temperament patterns. Keirsey identified four types of temperaments based on the combination between the four pairs of opposite preference. They are as follows: Dionysian Temperament or SP type (ISTP, ESTP, ISFP, ESFP); Epimethean Temperament or SJ type

(ISFJ, ESFJ, ISTJ and ESTJ); Promethean Temperament or NT type (INTP, ENTP, INTJ, and ENTJ) and Apollonian Temperament or NF type (INFJ, ENFJ, INFP, and ENFP).

Kirton (1992) developed the Adaptor-Innovator theory, which defines and measures thinking styles of people with particular reference to creativity, problem solving and decision making. According to Adaption-Innovation theory everybody can be located on a continuum ranging from highly adaptive to highly innovative according to his or her score on the Kirton's Adaption-Innovation Inventory. Kirton identifies two types of problem solving styles – adaptors and innovators. Adaptors apply in problem solving generally recognized theories, policies, customary viewpoints or paradigms. Much of their effort is in improving and 'doing better'. Innovators tend to change the existing paradigm in pursue of a solution. They are less concerned with 'doing the things better' than with 'doing things differently'.

Most of the problem solving styles classifications are based on large-scale personal constructs. Those approaches adopt a rather general view and apply the concept of thinking styles to problem solving styles. It seems logical to take into account the complexity of the process and the contribution of so many constructs either cognitive or affective. However if the task is to design a learning environment for problem solving that takes into account problem solving styles of the users, then a straightforward approach might be more appropriate. For the purposes of the current study, problem solving styles are defined according to the stages of the general problem solving cycle. It implies that people have different level preferences in one or few stages of problem solving process. For instance, a person may have a very strong preference toward idea generation, strong preferences for information collection, moderate capabilities in idea selection and low potential in idea implementation. If names have to be attached to these preferences then problem solving styles could be seeker, diverger, converger and doer. Seeker is strong in information collection. Diverger has abilities to create alternatives. Converger easy selects an appropriate idea among many generated. Doer usually is expected to be good in solution implementation.

The next section 2.7 'Problem solving methodologies' present some popular problem solving approaches that are rely on the on creative abilities and knowledge, and try to develop problem solving styles. These methodologies integrate concepts about problem solving process, report some basic principles and apply specific problem solving techniques.

2.7 Problem solving methodologies

This section will introduce several problem solving methodologies such as brainstorming, synectics, rational approach, problem solving potential analysis, and soft system. They are integrated systematic approaches developed to support people confronted with ill-structured situations. These methodologies are based on specific principles, have a particular structure and apply some techniques. Section 2.7.1 describes the principles and the structure of brainstorming. Section 2.7.2 presents the background and the procedure of Rational approach to problem solving. Section 2.7.3 discusses the theoretical framework and the guidelines of Soft System Methodology. Section 2.7.4 introduces to psychological, states, operational mechanisms and the process of synectics.

2.7.1 Brainstorming

Brainstorming is probably the most popular among problem solving approaches. It is mostly a group problem solving method involving interactions between group members and supporting a mutual beneficial effect between them. Certainly, it does not mean that an individual could not use the principles, rules, and procedures of this methodology.

There are two principles behind the brainstorming procedure – postponed judgment and quantity leads to quality. Initially brainstorming has been developed in order to deal with one of the most frequently occurred breakdowns in problem solving – criticism. The principle of the postponed judgement is to allow a flow of ideas without any concern about whether an idea is practical, important, or relevant. It does not mean that an evaluation is not taking place. The judgement is postponed until later, when the process of idea generation has stopped.

The principle of quantity breeds quality means that the greater the number of ideas produced the greater the probability of arriving at a successful solution. An additional reason has been that the first solution rarely turns out to be the best one. Brainstorming has been linked mostly with its four rules listed below:

- Criticism is not allowed
- Free-wheeling is encouraged
- Quantity is wanted
- Combination and improvement are required.

Criticism is ruled out is very much linked to the principle of deferred judgement. The participants in a brainstorming session are required to contribute constructively, suggesting ideas without criticizing the ideas of others. Criticism is considered as a ‘killer’ of ideas.

According to the principles of *freewheeling*, everybody is encouraged to submit without fear everything that comes to his/her mind. The wilder is an idea, the better. This is a way of breaking dominant thinking patterns and developing original solutions. The rule of *quantity is wanted* restates the principles of quantity breeds quality. The more ideas generated, the higher the probability to reach a good solution. The principle of combination and improvement encourages building upon the ideas of others, formulating better solutions. The principles and the rules of brainstorming are to establish and maintain an atmosphere for producing freely and without tensions creative and speculative ideas, firing the imagination of group members. The rules of the brainstorming are implemented within the procedure of method.

There are some modifications of the classical brainstorming. Some of them among others are ‘Brainwriting Pool’, ‘Collective Notebook’, ‘Gallery Method’, ‘Method ‘6-3-5’, ‘Philips 66’, ‘Pin Cards’, and ‘Nominal Group Technique’.

2.7.2 Rational Approach

The rational or ‘common sense’ approach to problem solving is based on good managerial practices. It is also referred to as a ‘KT’ method after the initials of the names of its originators Kepner and Tregoe (1981, cited in Van Gundy, 1997). It provides a systematic framework for shaping problem solving activities. It claims to support people in what, when, where, and how to do in problem situations.

Kepner and Tregoe have identified four patterns of thinking that distinguishes the good and bad managerial practice: situation appraisal, problem analysis, decision analysis, and potential problem analysis

The purpose of the Situation appraisal is to provide a picture of what is going on and what is needed to be done. This stage includes several tasks: recognizing concerns, dividing concerns into manageable components, setting priorities, and planning the resolution of concerns.

Problem analysis consists of the tasks such as definition of the problem, description of the problem in the terms of what it is we are trying to explain; where the problem is observed; when the problem happens; how serious, likely and widespread the problem is, and generation of possible causes and testing for the most probable causes. The most important step in definition of the problem is to write up ‘deviation statement’. It is a short problem definition about the observed gap between actual and expected performance. Description of the problem requires the collection of information about the problem. The next important step is looking for a similar situation. This narrows the field of possible causes. People have to test whether the cause identified as possible would rise to all the symptoms.

Decision analysis consists of six steps: decision statement, establishing a set of criteria, evaluating alternatives, and choose. Decision statement should articulate what we would like to achieve. Usually it includes a short description of the case, several brainstormed alternatives, some limitations concerning these alternatives, and at the end a clear formulation of the decision to be made. Selection and classification of criteria is about a set of criteria for comparing the alternative solutions.

Potential problem analysis is aimed at identifying the eventual problems during implementation of the solution and developing a contingency plan, assigning some preventive actions to eliminate or at least to limit their impact.

2.7.3 Soft System Methodology

Soft System Methodology (SSM) is a complete problem solving strategy to cope with complex, ill-structured situations (Checkland & Scholes, 1990; Hicks, 1993). The predicate 'soft' is to distinguish it from so called 'hard' methodologies that deal with technical problems predominantly. The attempts to apply the 'hard' approach to people problems are generally seen as inappropriate. SSM might be thought as consisting of seven stages:

- Finding out
- Rich picture, primary tasks and issues of concerns
- Root definitions of relevant systems
- Conceptual models
- Comparing the Rich Picture with Conceptual Models
- Feasible, desirable changes
- Action to improve problem situation

The Finding out stage is aimed at gathering information about the situation that has been considered as unstructured. Both 'hard' and 'soft' types of data are needed to get a complete picture about the situation. The 'hard' data contains the factual and objective information about structure and the processes in an organization, products, data flows, important individuals, and any quantitative data.

Once the primary and secondary data are collected, the situation is presented by a cartoon-like diagram, called 'Rich Picture'. After the pictorial representation of the situation is ready, a reflection on it is needed in order to identify the tasks that organization was establish to perform, the activities they will design in order to cope with the situation, and the main issues of concerns.

A 'Root Definition' is a concise verbal description of the system that is modelled and when compared to the reality would inspire ideas for changes that could solve the problem. It shows the essence of what is to be done, why it is to be done, who is to do it, who is benefit or suffer from it, and what and how the environment limit the activities.

While ‘Root Definition’ is what an idealized system might be, a ‘Conceptual Model’ presents all the activities necessary to satisfy the requirements of ‘Root Definition’. The very strong rule here is the requirement to develop a ‘Conceptual model’ directly out from ‘Root Definition’.

The idea behind a comparison between a ‘Conceptual Model’ and the reality expressed by a ‘Rich Picture’ is to provoke a debate about possible changes that could improve the current situation. Four ways of making the use of the potential of comparison are outlined: ‘making several models and looking for main differences’, ‘producing a checklist of questions about particular components’, ‘designing a scenario capturing the essentials of the behaviour of the conceptual model in the reality’, and ‘constructing a model of a part of the reality’ similar to the conceptual model to provoke a comparison.

The comparison between the model and the reality is to evolve and support a debate among the people concerned to generate some ideas and to suggest some systematically desirable and feasible changes in the current situation.

The last step is to implement the changes into the reality. Usually the changes are defined as structural, procedural and attitudinal. The types of changes are relatively easy to specify but relatively difficult to carry out. It has been recommended that special attention to be paid to the possible consequences.

2.7.4 Synectics

The word 'synectics' comes from Greek and means joining together of different and apparently irrelevant elements (Van Gundy, 1997). Synectics uses analogies and metaphors to both problem analysis and development of possible solutions. Two operational mechanisms are applied to accomplish these activities: making the familiar strange and making the strange familiar. The former is designed for better problem understanding. The later is designed to help the problem solver go away from the problem in order to develop more unusual solutions. The purpose of these mechanisms is to create five psychological states that can facilitate creativity:

- Involvement and detachment
- Deferment
- Speculation

- Autonomy of object
- Hedonic response

The next section 2.7.4.1 introduces each of these psychological states. The Section 2.7.4.2 presents the operational mechanisms of the synectics. The Section 2.7.4.3 describes the process of the synectics.

2.7.4.1 Psychological states

The psychological state of 'involvement and detachment' concerns the feelings people experience about their relations with a problem. Involvement is about the feeling of being tied to a problem to such an extent that it cannot be avoided. Detachment is an opposite feeling when a problem solver feels a distance between him/herself and the problem. Involvement provides the sense of closeness needed to understand the problem while the detachment provides a separation needed to view the problem objectively. The 'Development of deferment' helps a problem solver to avoid producing premature, obvious and immediately available solutions. The psychological state of 'Speculation' reflects the capacity of a group and the abilities of members to free up their minds, asking a question like: 'What would happen if…?' 'Autonomy of object' means that a solution appears to have an identity and it is not longer in the control of the problem solver. When a feeling occurs as being on the right track of solving a problem without having validating evidence this is a 'Hedonic response'. A hedonic response is generally accompanied by a pleasurable sensation similar to that which accompanies intuition or inspiration, known also as the "aha" experience.

2.7.4.2 Operational mechanisms

The operational mechanisms are the working tools of the synectics process. They are responsible for making the familiar strange and to avoid looking at a problem in a conventional and familiar way. Four types of analogies are the operational mechanisms of the synectics. They are personal analogy, direct analogy, symbolic analogy, and fantasy analogy.

To use a personal analogy is to put yourself at the place of an object, person, or idea. Direct analogy attempts to describe a clear and straightforward relationship between the problem and some object, or idea. Symbolic analogy requires an essence, or most substantial parts of a problem to be expressed in a symbolic and highly evocative way. Books, movies or songs titles could be used for this purpose.

The question stimulating a fantasy analogy may sound like: 'In what ways do we in our wildest fantasy desire something'? The best use of this analogy is in the initial stage of making familiar strange. The operational mechanisms are implemented in the process of synectics.

2.7.4.3 Synectics process

The main stages of a typical synectics meeting are:

- *Problem as given*. A general statement of the problem is given to the group.
- *Short analysis of the problem*. The purpose of this stage is to make the strange familiar. The group can use metaphors and analogies or other techniques.
- *Purge*. The major objective of this stage is to eliminate the rigid and superficial solutions.
- *Problem as understood*. This stage begins with the selection of a part of the problem to work on. The participants describe how they see the problem. After recording the different viewpoints, the leader consults with an expert and selects for further analysis one of the ways of looking at the problem.
- *Excursion* ("Artificial vacation", "Holiday from the problem"). The leader directs the group in further examination of the problem with a goal of making the familiar strange. After generating a number of analogies, the leader might then select one for more detailed analysis and elaboration.
- *Fantasy force-fit*. A force-fit between last analogy used in the 'Excursion' stage and the problem as understood is proposed. Using of fantasy to produce more creative responses is suggested. The group should play with the problem and the analogies until a new way of looking at the problem is achieved.
- *New problem as understood*. The process of synectics end up with a production of a viewpoint (a new way of looking at the problem) that could lead to a solution, or to problem as understood. If a viewpoint is produced, then it should be considered tentative until a solution has been developed, implemented, and evaluated. If a new problem as understood is the end result, then the process should be repeated using the 'problem as understood' in attempt to develop a viewpoint.

2.8 Summary

The goal of this section was to provide some suggestions as how the theories, research and practice in problem-solving paradigm could be beneficial for improving the educational and training design activities. The section outlined main directions of the research on problem solving. The negative conditions for effective problem solving were identified and approaches to deal with this issue were presented. Basically two theoretical and research framework were discussed: Those that are concerned with 'reducing complexity' and those that try to 'manage complexity' of problem solving. While some information about reducing complexity approaches was given, the focus was put on the 'managing complexity' approaches. There are number of ideas coming out from problem solving paradigm that might be useful for solving design problem in education and training. They may be listed as follows:

- The ideas that designing educational and training problems should be considered in systematic terms as a process consisting of several stages which are aimed at specific targets. There are some stages that are repeated in almost all classifications of problem solving process. These are information collection, problem definition, idea generation, solution selection and solution implementation with possible loops between them. It seems natural in an ill-structured situation to start with the gathering and analysis of information. One of the essential characteristics of an ill-structured situation is incomplete, complex and fuzzy information. Identifying what is the real problem is crucial in the problem solving process.
- *The idea that in each of the stages both divergent and convergent activities are needed.* Divergent activities are needed for broadening the perspectives to the issue. Convergent activities narrow the scope of the search, organizing and selecting ideas. Usually each stage begins with some specific divergent activities, before some convergent activities are organized. The overview of research in the field of problem solving gave some insights for elaboration on this idea. Knowledge elicitation, reflection, representation and creation are identified as important functions in each of the stages of problem solving. Certainly these functions are assigned different roles in the various stages of problem solving.
- The idea of promoting a set of creative problem solving techniques to support the activities in each of the stages of problem solving. The support should be differential, as these techniques preferably should facilitate knowledge elicitation, reflection, representation and creation in the phases of information collection, idea generation, idea selection and idea implementation. The rules of brainstorming, guidelines, principles and operational mechanisms, the concrete procedures of creative problem solving techniques and the comprehensiveness of problem solving methodologies are insights that could be taken into consideration when designing a method that supports solving ill-structured design problems. It is possible however that new techniques will need to be developed depending on the context and the objectives of the design.
- The creative problem solving techniques within the framework of a problem solving methodology should be considered as special heuristics. They guide systematically

educational designer to solve a specific problem in an effective and efficient way, channelling his or her expertise.

- The idea of problem solving styles was defined as the individual preferences people may have in organizing knowledge in problem solving. However most of the research reflects general constructs based on fundamental personality characteristics. It might be assumed that the problem solving styles of people can be defined to the extent to which they have strong preferences to one of the points in the general problem solving cycle - information collection, idea generation, idea selection and idea implementation. The four types of problem solving styles that were identified for the purposes of the current study (Section 2.6.3) are seeker, diverger, converger, and doer.
- The idea of the existence of negative problem solving syndromes, mental blocks and barriers which impede the effective problem solving. Knowing what they are might help in assigning some relevant interventions in overcoming their negative effects.
- The idea of applying the factors constituting the creative process as a rational basis for scoring on the creative production of people. Fluency, flexibility, originality and elaboration could be used for this purpose.
- The idea implicitly stated that we need some cultural artefacts to deal with the reported limitations of human information processing. The question is not to ‘reduce complexity’ but rather to ‘manage complexity’ in problem solving. Mapping approaches might play important role in this. The Chapter 4 about mapping approaches provides more details as why and how it can be done.

Chapter 3. Theoretical foundations of the SMILE learning environment

This chapter discus some instructional theories that could contribute to the design and development of interactive learning environment of a tool supposed to support solving design problems. The attention is focus on instructional approaches that manage the complexity of the learning situations rather than reduce the complexity of the learning situations. Managing complexity means organizing learning within a context of real-life tasks while individualizing study. The research question that this chapter addresses is which instructional design theories and approaches constitute the theoretical background for designing the interactive learning environment of the SMILE Maker? The chapter makes an overview of cognitive flexibility theory (Section 3.1), cognitive apprenticeship approach (Section 3.2), and theory of individual differences (Section 3.3).

3.1 Cognitive flexibility theory

Cognitive flexibility theory (Spiro & Jehng, 1990) adopted Wittgenstein’s “criss-crossed landscape” metaphor (1988) to apply to any complex and ill-structured knowledge domain. Rather than *reducing the complexity* of the ideas for purposes of theoretical parsimony Wittgenstein treated the philosophical topics as complex landscape and sketched them as sites in that landscape. He arranged these sketches as local regions of the landscape to form a kind of album. The “album” would represent different perspectives of the conceptual landscape. The same issues (or cases) would reappear in different contexts, analysed from different perspectives.

The authors of cognitive flexibility theory (Spiro & Jehng, 1990) have gone beyond the Wittgenstein’s metaphor. They use this metaphor to form the basis of a general theory of learning, instruction and knowledge representation. One learns by criss-crossing conceptual landscapes. Instruction involves the provision of learning materials and channel multidimensional landscape explorations under the active initiative of the learner (as well as providing expert guidance and commentary to help the learner to derive maximum benefit from his or her explorations). Knowledge representations reflect the criss-crossing during the learning. By criss-crossing conceptual landscapes, highly interconnected, web-like knowledge structures are built that permit great flexibility in the way the knowledge can potentially be assembled for using in comprehension or problem solving. The emphasis in cognitive flexibility theory is shifted from intact cognitive schemata retrieval to flexibility of situation specific schemata constructing.

Cognitive flexibility theory emphasizes on repeated presentations of the same material in rearranged instructional sequences and from different conceptual perspectives. Hypertext is claimed as the most appropriate mode for promoting the ideas of cognitive flexibility theory. The authors of cognitive flexibility theory believe that hypertext development should be related to underlying theories of cognition and instruction. At the same time they do not believe that an additional cognitive load placed on some learners by non-linear instruction is always desirable. According to Spiro et al (1991), hypertext is appropriate for advanced learners who try to master the complexity of a situation and prepare for transfer in ill-structured knowledge domain.

Cognitive flexibility theory designs instruction as a set of mini cases. Getting familiar with some mini cases learners are presented to elaborated versions of the same mini case in different context. Then a more complete case is followed. In this way instruction addresses the complexity of situation while reducing the cognitive overload on learners.

Cognitive flexibility theory could contribute to designing an interactive learning environment with the following ideas:

- *Presenting the same content in different ways*. Strictly speaking cognitive flexibility theory does not pay special attention to the individualisation of instruction. What it basically says is that everybody should be introduced to the same content but in a sequence of different presentation formats. This is a valuable idea and one can elaborate on it to design user-centred learning environment.
- *Matching learning method to instructional goals*. The proponents of the cognitive flexibility theory try to manage complexity instead of reduce complexity of learning situations. Cognitive flexibility theory proposes a learning approach that fits the purpose of forming high order problem solving skills.
- *Matching the external mode of presentation to the learning method*. Cognitive flexibility theory promotes hypertext as the most appropriate mode of forming complex cognitive skills. Web-like knowledge provides flexibility for shifting from one perspective to another. It brings the idea that Web delivery mode might be a good solution for designing interactive learning environment aimed at developing complex cognitive skills. From another side, adherents to the cognitive flexibility theory claim that the non-linear format of presentations of the content is not suitable for accomplishing a simple learning task. Going further it could be stated that it is not only question of complexity/simplicity but also a matter of individual capacity and preferences. Some people are not fit to the non-linear format of presenting the content of learning.

3.2 Cognitive apprenticeship approach

The cognitive apprenticeship method is aimed primarily at teaching the processes of how experts handle complex tasks (Collins, Brown & Newman, 1989). One of the most important characteristics of the apprenticeship approach is that the target skills are instrumental to the accomplishment of meaningful tasks. Conceptual and factual knowledge are used in solving problems and carrying out tasks. Apprenticeship includes the learning of knowledge and skills in their social and functional context.

The cognitive apprenticeship approach refers to learning-through-guided-experience on cognitive and metacognitive skills and processes. Applying apprenticeship methods to cognitive skills requires the externalisation of processes that are usually carried out internally. The externalisation of relevant processes makes observation a primary means of building a conceptual model of a complex target skill. The instructional methods of the cognitive apprenticeship approach bring tacit intellectual processes into open, where students can observe, enact, and practice them with help from the teacher and from the other students.

Cognitive apprenticeship requires special techniques for developing self-monitoring skills. It encourages reflection on expert performance by focusing students' observation and comparison directly on identifying the characteristics of both their own and expert's performance.

The cognitive apprenticeship framework of designing and evaluating learning environments generally consists of four dimensions: content, method, sequence, and sociology (Collins, Brown & Newman, 1989).

Content

The cognitive apprenticeship framework includes four categories of expert knowledge:

- *Domain knowledge* including the conceptual and factual knowledge and procedures explicitly identified with a particular subject matter. It should be learned by students in a real problem solving situation.
- *Heuristic strategies* - generally effective techniques and approaches for accomplishing tasks that might be regarded as "tricks of the trade" (Collins, Brown & Newman, 1989). Although most of the heuristics are tacitly acquired by experts through the practice of problem solving, there are attempts to present heuristics explicitly.
- *Control strategies* represent the knowledge that experts have about managing problem solving. Control strategies require reflection on the problem solving process. They

operate at many different levels and have monitoring, diagnostic and remedial components.

- *Learning strategies* are strategies for learning any kind of content. They range from general strategies for exploring a new domain to more concrete strategies for extending or reconfiguring knowledge.

Method

According to the cognitive apprenticeship approach the teaching methods should be designed to give students the opportunity to observe, engage in, and discover experts' strategies. Collins, Brown and Newman (1989) include in their cognitive apprenticeship framework six methods classified into three groups.

- Core cognitive apprenticeship methods, designed to help students to acquire an integrated set of cognitive and metacognitive skills through processes of observation and guided practice. These include modelling, coaching and scaffolding.
- Methods, such as articulation and reflection, that are designed to help students to focus their observations on expert problem solving and gain an access and control on their problem solving strategies.
- Methods aimed at encouraging the learners' autonomy in carrying out expert problem solving processes and in defining or formulating the problems to be solved. Such method is called exploration.

Sequencing

In order to facilitate the development of robust problem solving skills the cognitive apprenticeship approach identified three main principles of guiding the sequencing of learning activities (Collins, Brown & Newman, 1989).

- *Increasing complexity* refers to the construction of a sequence of tasks where more skills and concepts necessary for expert performance are required. As main mechanisms for helping students to manage increasing complexity are mentioned the efforts to control task complexity and scaffolding.
- *Increasing diversity* refers to the construction of a sequence of tasks in which a variety of strategies or skills are required. Tasks requiring diversity of skills and strategies should be introduced so students learn to distinguish the conditions under which they do or do not apply already learned skills.

- *Global before local skill principle* requires students to build a conceptual model of the target skill before attending to the details. Such cognitive models also acts as a guide for the learners' performance, improving their abilities to monitor his own progress and to develop self-correction skills.

Sociology

Collins, Brown and Newman (1989) describe five critical characteristics affecting the sociology of learning.

- *Situated learning* refers to confronting learners to an authentic environment where they have to apply their knowledge and skills. Thus learners understand the purposes and uses of the knowledge they are learning, learn by active using knowledge rather than passively receiving it, and learn the different conditions under which their knowledge can be applied.
- *Culture of expert practice* refers to the creation of learning environment where participants actively communicate about different problem solving skills.
- *Intrinsic motivation* stress the importance of creating learning environment in which students perform tasks because they are intrinsically related to an interesting goal.
- *Exploiting cooperation* refers to having students work together in a way that fosters co-operative problem solving. It is regarded both as a powerful motivator and as a powerful mechanism for extending learning resources.
- *Exploiting competition* is a strategy of giving students the same task to accomplish and then compare production.

An important characteristic of the cognitive apprenticeship framework of designing and evaluating learning environments is that it could be formalised and embedded in a computer-supported instruction.

The supporters of cognitive apprenticeship approach do not claim that it is the only way to learn (Collins, Brown & Newman, 1989). It remains the method of choice.

Cognitive apprenticeship approach proposes some ideas that could be beneficial for designing interactive learning environment. They are listed as follows:

- Developing very close relationship between learning and problem solving. It supports learners to study how to solve real problem.
- Considering knowledge and skills as operational for solving problems.
- Representing the cognitive processes as pieces of observable behaviour.

- Emphasising on the role of reflection on examples of expert behaviour and involvement of learners in practice expert behaviour.
- Emphasising the importance of coaching, scaffolding and modelling in developing skills for problem solving.
- Providing special support for managing complexity of learning situations.
- Emphasising on the role of co-operative and concurrent group learning and on the communication within the community of novices and experts.

3.3 Theories of individual differences

The issue of individual differences has been attracting the attention of instructional designers and educational technologists for a long period of time. The effectiveness of instruction is a function of how adequately individual differences are treated. There is agreement about the importance of individualisation for instruction and a considerable disagreement about the way of dealing with the complexity of the issue. It is challenge to design a learning environment, managing a very large range of individual differences. Many psychological constructs interrelate and many external factors have to be taken into account. Some of the most crucial issues are: the large number, diversity, and multi-layers structure of individual constructs; instability of personal characteristics over time, space and task; and one-side development of personal preferences. Individual differences taxonomy may consist of the following constructs: abilities, cognitive styles, learning styles, prior knowledge, causal attribution, locus of control, personality traits, and achievement motivation. It is beyond the scope of this chapter to make a comprehensive overview of all individual difference constructs. Attention will be focused mainly on cognitive and learning styles as far as they are integrative constructs including ability, background and personality dimensions. Cognitive and learning styles play an intermediate role between abilities and prior knowledge. In addition there is not a unified classification of cognitive and learning styles. What some classifications called ‘cognitive styles’ in other classifications is defined as ‘learning styles’. Attention to learner’s locus of control will be given because it has a strong impact on structuring interactive learning environments. The section discusses cognitive styles (Section 3.3.1), learning styles (Section 3.3.2), and locus of control (Section 3.3.3).

3.3.1 Cognitive styles

Entwistle, (1988) reserved the term cognitive style for stable, trait-like consistency in approach to attending, perceiving, and thinking. Messick (1994) described cognitive styles as characteristic modes of perceiving, remembering, thinking, and problem solving. They are reflective information processing regularities that have developed around underlying personality trends. Jonassen and Grabowski (1993) stated that cognitive styles represent stable traits that learners employ in perceiving information and stimuli while interacting with their environment. According to Riding and Rayner (1998) the notion of style is used to describe a set of individual qualities, activities or behaviour sustained over a period of time. It reflects a basic human need to create a sense of identity, which is the essence of individuality. Riding and Rayner (1998) claimed that the significance of awareness of style is its potential for enhancing and improving human performance in a variety of contexts. Cognitive styles are tendencies that cut across content and that are rather persistent in persons. The identified 'temporal stability' of the style makes it a constant aspect of a person's psychology. It is impossible for persons to 'switch off' their style.

Cognitive style might be understood better by comparing it to the constructs such as ability and learning strategy. Here differences between cognitive style and ability are presented.

- *Content and level of cognition versus mode of cognition.* Intellectual abilities refer to the content and the level of cognition (What? and How much?). Cognitive style reflects the manner or mode of cognition (How).
- *Unipolarity versus bipolarity*. Ability is a unipolar construct - high amounts of ability are always preferable. None of the poles of a particular cognitive style is better that another one.
- *Value-direction versus Value-differentiation*. High amounts of abilities are uniformly more adaptive. Each pole of style dimension has different adaptive implications.
- *Domain-specific versus domain-independent*. Ability is a specific for a particular domain of content or functions such as verbal, numerical, spatial, or memory ability. Cognitive style cut across domains of ability, personality and interpersonal functioning.

Cognitive style might be distinguished also from the learning strategy construct using a disjunctive framework:

- *Inbuilt nature of the style versus learned nature of the strategy*. Cognitive styles are inbuilt constructs of personality. The learning strategies are learned as a way of adapting to situation for which the natural cognitive style is not ideal.
- *Conscious selection of strategy versus spontaneously selection of a style*. Cognitive strategies refer to conscious decisions among alternative approaches as a function of task requirements and situational constraints. In contrast, cognitive styles are spontaneously applied in a wide scope of situations.

- *Stability versus Flexibility*. Styles are stable and relatively pervasive across different areas. Strategies in opposite are more flexible to change through the instruction. What is important to say here is that individuals could not only learn to use a variety of problem solving and learning strategies that are consonant to their cognitive styles, but could also learn to shift to less congenial strategies that are more effective for a particular task.

Jonassen and Grabovski (1993) identified the following representative sample of cognitive styles: field dependence / field independence; cognitive flexibility; impulsiveness / reflective; focal attention; cognitive complexity / simplicity; visual / haptic; visualiser / verbaliser; levelling / sharpening; serialist / holist; and analytical / relational. Some of the most referred cognitive styles such as field-dependence/field independence, serialist/holist, impulsivity/reflectivity, and verbaliser/visualiser, are discussed in more detail.

Field Dependence - Field Independence.

Field dependence/independence refers to the extent to which a learner perception is influenced by environment or context (Witkin & Goodenough 1981). Field dependent students experience difficulties in finding the information they are looking for because other contextual stimuli tend to impede it. Field independent learners can easily distinguish the relevant information from its surrounding components. Field independents are more likely to create their own models when trying to understand a perceptual field. Field dependants are more fixed to the explanation format that has been proposed and have a tendency to accept the information without restructuring and reorganising it. In summary, field dependant students prefer a more structured learning environment with well-organised material, while field independents prefer a learning context with minimal direction and maximum resources.

Impulsivity – Reflectivity.

Impulsivity/Reflectivity distinguishes people according to the tendency of postponing initial response and reflecting on it before answering rather than the tendency of quick, impulsive response (Kagan, 1965, cited in Jonassen & Grabowski, 1993). Impulsive people, by rule, respond faster and make more mistakes. Reflectors answer slower but commit fewer performance errors. Reflective people tend to analyse the information, to consider carefully all options, and to generate several alternatives before going to implementation. Impulsive people reach a decision quickly. After a brief review of options, they go straightway to implementation of the first idea that has come in mind.

Serialist – Holist

The Holist/Serialist cognitive styles has been defined according to the two different ways of selecting and organising information in learning complex subject matter: building an overview of the topic itself or building concrete operations (Pask, 1988). Holists prefer global approach to a learning material using broad descriptions. They often focus upon several aspects of the topic at the same time and work simultaneously at several different levels of thinking. Holists tend to relate everything with everything in a complex multilevel information structure. This is a hypotheses-driven style. Serialists usually adopt an 'operation' approach to learning. They use step-by-step approach focused on details and procedures and often conceptualise information in a sequence structure. This is a data-driven style.

Huai (2000) is her doctoral dissertation assumed a link between cognitive style (holist/serialist), type of memory (short term/long term), concept mapping method (serialistic/globalistic) and learning outcomes. The results confirmed the links between cognitive styles and types of memory. Holists try to compensate their weak short-term memory with a top-down processing mapping approach. Serialists having good short-term memory adopt a step-by-step approach. The research did not find links at a significant level between cognitive styles and concept mapping methods.

Verbaliser – Visualiser

The Verbaliser /Visualiser cognitive style measures the preference of people to attend and organise visual or verbal information (Jonassen & Grabowski, 1993). Some people learn better from diagrams, graphics and pictures, while others prefer to process information by reading or listening. The immediate educational implication of this cognitive style is the deliberate attempt to build a learning environment with both visual and verbal stimuli.

3.3.2 Learning styles

Learning style is a construct to reflect people's learning habits and their typical behaviours in a situation of learning. For instance, some people feel more comfortable with theoretical models, others are keen more on practical implication of the theoretical principles, while a third group prefers examples to reflect on it. Riding and Rayner (1998) classify the models of learning style in four groups:

- Style models based on the learning process
- Style models grounded in orientation to study
- Style models based on instructional preference
- Style models based on cognitive skills

What follows are descriptions of three of the most popular learning style conceptions: Kolb's learning styles, Rayner and Riding learning styles analysis, and Honey and Mumford's learning styles.

3.3.2.1 Kolb's learning styles

Kolb (1998) identified four types of learning styles: diverger, assimilator, converger, and accommodator. These learning styles are based upon experiential learning theory. Each of the learning styles is a unique combination of two out of four modes of learning preferences: concrete experience, reflective observation, abstract conceptualisation and active experimentation. Concrete experience and reflective observation form the learning style of Diverger. She or he is able to see a concrete situation under several perspectives and to generate several alternatives for a solution. Assimilator relies on abstract conceptualisation and reflective observation. People with this orientation to learning task tend to build theoretical models. Converger is situated on the cross point of abstract conceptualisation and active experimentation. Persons possessing this style prefer a well-structured learning situation with one correct answer or solution. Accommodator style is based on concrete experience and active experimentation. Accommodators prefer to do things and to be involved in new activities. They rely very much on a trial and error approach.

Oughton and Reed (2000) measured the effects of the four learning styles according to Kolb and level of prior hypermedia knowledge on several features of concept mapping production such as number of concepts, number of links, level of depths, preserved concepts, omitted concepts, and added concepts. An interaction effect was found between learning styles and hypermedia knowledge as assimilators and divergers were the most productive on their maps and had the deepest level of processing on their maps.

In contrast, Ayersman and von Minden (1995) reported no significant difference among Kolb's learning styles in relation to hypermedia knowledge. They explained the result with the opportunities hypermedia created for each of the learning styles to find what it needs.

3.3.2.2 Riding and Rayner cognitive styles analysis

Riding and Rayner (1998) proposed an integration of style models into two style families - the Wholist-Analytic and the Verbaliser-Imager. In the former they included the styles such as Field Dependency/Field Independency, Impulsivity/Reflectivity, Convergent/Divergent, Holist/Serialist, The Style Delineator, Assimilator/Explorer, Adaptor/Innovator, and Cognitive Style Index. The style included in the later classification is Verbaliser/ Visualiser. As it can be seen from this classification Riding and Rayner do not have a need to distinguish between learning and cognitive styles. The aim of their work is to overcome problems associated with the positive assessment of only one dimension and to find a satisfactory and efficient means of assessing both dimensions of a style. They developed the Cognitive Styles Analysis (CSA) instrument as an attempt to integrate a theory of learning style into a single construct. Their instrument reflects previous research on cognitive functioning related to learning performance in a variety of learning tasks.

3.3.2.3 Honey and Mumford's learning styles

The learning styles according to Honey and Mumford (1992) are activist, reflector, theorist, and pragmatic. They described the learning preferences in a relation to the four stages of the general learning cycle - experiencing, reviewing, concluding and planning.

- *Activist is associated with experience*. The philosophy of activists is 'I will try anything once'. People dominated by this style prefer first to act and than to think about consequences. They are very bored with analysis of the situation and implementation of the solution.
- *Reflector is associated with reviewing*. People possessing this style like to consider their own experience and the experience of others from many different perspectives. Before going to any decision they prefer to analyse carefully the data.
- *Theorist is associated with concluding*. Persons with this style are very good in assimilation of the facts into coherent theories. They consider everything in the light of particular assumptions, principles, theoretical models and systems. Their philosophy can be expressed by 'If it is logical it is good'.
- *Pragmatist is associated with planning*. Pragmatists always look for the practical value of any idea. They would like to try the theories into practice. Their philosophy is 'If it works, it is good'.

The idea of defining learning styles according to the phases of a general learning cycle sounds quite promising. Learning styles as individual constructs are defined against stable criteria of learning cycle stages. The analysis of different instructional theories revealed a pattern of instructional events across them. All of the instructional approaches apply one or several instructional events such as explanation, examples, procedures and practice. Explanation provides definitions, background information, and theoretical framework of the issue under consideration. Examples as the name indicates may consist of affirmative and counter examples, templates, demonstrations and simulations. Procedures are about step-by-step approach or set of guidelines and heuristics of how the things can be done. Practice is to apply knowledge and skills on an object, just to do the things. People develop very strong, strong, moderate or low preferences to these instructional events. Learning styles could be defined against those instructional events. Because of the common background a link between learning styles of Honey and Mumford (1992) and the four instructional events might be assumed and further explored.

3.3.3 Locus of control

Locus of control reflects personal expectations and causal attribution about factors of success and failure. It is defined as an individual's generalised attitude or expectancy regarding the nature of the causal relationship between behaviour and its consequences. The locus of control construct is a "generalised expectancy which pertains to generalisation about causality" (Lefcourt, 1980). It affects a variety of behavioural choices along with specific expectancies to determine the choice of behaviour. Two types of locus of control are identified: external and internal. People with internal locus of control attribute causes of success and failure to themselves, their efforts, abilities, and competencies. Externals attribute success and failures to factors such as chance, fate, availability of help, and easy task.

A number of studies have examined the way in which locus of control relate to students' achievement. Fryans and Maehr (1979) investigated the relationship between task selection and achievement and found that students who attributed achievement to the outcome preferred tasks in which competence was necessary. Students who believed that success was due to luck, avoided ability tasks and preferred games of chance. Daniels and Stevens (1976) compared the teacher-centred classical instructional approach and the self-directed instruction - 'contract plans' instructional model, in relation to students' locus of control characteristics. They discovered that internals experienced higher achievement using a self-directed instructional strategy, whereas externals experienced higher achievement under teacher controlled method. Holloway (1978) concluded in his research that internal students may benefit mostly by being presented with 'personalised system of instruction' while external subjects appreciate participation in more traditional models of instruction.

It could be concluded that the achievement behaviour is in some way related to students' locus of control and to model of instruction. It could be expected that students' achievements might be affected by the interference between the two constructs (achievements and way of instruction) rather than by the any one of them as a single factor. The learning locus of control can be defined according to the extent to which people prefer well structured or a more loos learning environment. The learning locus of control continuum consists of two extremes: external and internal. Externally controlled people rely on a well-structured learning environment, while internals prefers to construct their own learning environment.

The research on individual difference constructs hardly suggests that they should be associated with total persistence and domination on learner behaviour across situations. One can be a reflector today and a pragmatist tomorrow. A person might be at the same time either an activist learning style or holist or serialist or visualiser or verbaliser cognitive style. A situation or a task could be a strong predictor for which learning preference will be dominant. Even the strongest proponents of the idea of individual preferences stability over time, space and task have made some remarks about the relative flexibility of styles' constructs. Keirsey and Bates (1984) argued that one could be an extravert in some degree as well as an introvert in some degree, or thinking type in some degree and feeling type in some degree. As time passes one preference may be strengthened or weaken. The researchers admitted that the question of whether the preferences are inborn or developed remains unsettled. Whether inborn or not the preferences become stronger through use. If, for example, a person uses his intuition, the intuition becomes more powerful. In contrary, if one does not use his thinking or judging, those preferences do not develop.

Sternberg (1994) raised the assumption that there may be pre-programmed dispositions that are difficult to change. Some people retain the less rewarded style despite the environmental pressure. But he also believes that the styles are largely determined by a task and a situation. The styles can be developed. An individual with a style inclination in one situation may demonstrate different style in another situation. Styles are not fixed, they are fluid.

Basically, people are complex in their abilities, traits and styles, certainly not in equal extent. Most of them develop, because of different reasons, (family background or education) one-side preferences: (for example, holist or serialist, activist or theorist) The real challenge is not only to adapt instructional conditions to particular individual characteristics but also to develop a more balanced style. Pask (1988) suggested that the achievement of full understanding of information required learning approaches, a holist-like global approach and a serialist-like local approach. Human learners are very capable of adapting to specific task requirements. They could learn to use not only a variety of problem solving and learning strategies that are "consonant to their styles, but could learn also to shift to less congenial strategies that are more effective for a particular task" (Jonassen & Grabowski, 1993). Buzan and Buzan (1996) claimed that although each of both right and left brain hemispheres is dominant in certain activities, they are both basically skilled in all areas.

The survey on individual differences has revealed some issues that could be formulated as follows:

- A large number and different levels of individual constructs such as ability, cognitive style, learning style, learning locus of control, personal type, and prior knowledge exists.

- Individual constructs are unstable over time, space and tasks.
- There is a need for developing versatility and flexibility in individual characteristics

A promising initial step to the first issue is the consideration that learning styles are integral cognitive and personality dimensions constructs. They are the most subsuming multi-layer categories containing abilities and cognitive styles. This is what is seen on the surface in a learning situation and this is what a designer should focus on.

In relation to the other two issues, the literature proposes at least four approaches to match instruction and the individual differences (Jonassen & Grabowski, 1993):

- Preferential match - capitalising on learner strength or preferences
- Remediation match - eliminating deficiencies in learner traits
- Compensatory match - supplanting skills or learner traits
- Challenging learner skills

The challenge, from the instructional point of view, is while staying on the strong points of individual preferences to correct the stylistic deficiencies of learners. The question should be not how to adapt to one's particular styles but rather to create a more versatile and flexible style. The practice of designing learning environment has developed basically two approaches of matching learning styles, teaching strategies and learning activities: adaptation and accommodation. The first type of design solutions assumes that it is possible to identify in advance the learners according to their learning styles. Then relevant teaching strategies could be assigned to the learning styles. The second approach is to construct a rich learning environment that accommodate all learning styles, where everybody can find what is appropriate for her/him. This proposes an in-built flexibility that meets the needs of all learners. It assumes the existence of preferences to learning while taking into account that they are not stable in the terms of time, subject matter, and interaction with other cognitive constructs.

Oughton and Reed (2000) measured the effects of the four learning styles according to Kolb and level of prior hypermedia knowledge on several features of concept mapping production such as number of concepts, number of links, level of depths, preserved concepts, omitted concepts, added concepts to mention part of them. An interaction effect was found between learning styles and hypermedia knowledge as assimilators and divergers were the most productive on their maps and they had deepest level of processing on their maps.

Ayersman and von Minden (1995) claimed that rather than adapting instruction to learners or adapting learners to instruction, the better option is designing a rich learning environment that accommodates individual differences of learners. The most appropriate technology for that purpose is hypermedia because of its flexibility and its potentially high level of learner control. Ayersman and von Minden (1995) formulated some practical suggestions for developing an interactive learning environment elaborating on the third design alternative:

- It is generally recognised that learning is best facilitated if there is a close correspondence between user's internal representation and the media's mode of representation.
- Despite the many alternative conceptions of individual differences, these conceptions appear to converge in the implication that individuals consistently exhibit stylistic preferences for the ways in which they organise stimuli and construct the meanings of themselves out of their experience.
- The mode of information presentation is optimal when matches to modality preferences.
- Rather than adapting the currently existing instruction to a diverse audience, the initial design of the instruction should incorporate the individual styles of learning. An instruction has to be developed so that it encompasses many different styles of learning within its rich design.

During a joint research project with Salford University in May 2000 on learning styles, 200 learning styles cases measured by the questionnaire of Honey and Mumford (1992) were analysed. The purpose was to identify tendencies and trends in the data, which might be helpful in designing the learning environment of a tool offering a method for solving design problems. Some additional variables were taken into account, reflecting on the students' comments on their learning styles. For example, some of them had strong preferences to two of the learning styles, but when reflecting on the results they reported a strong preference only to one of the learning styles.

Learning styles questionnaire is a part of Personal Management Development Journal within the framework of Management Development Module for the first year students of the Faculty of Business Studies. The goal of Personal Management Development Journal is to support students' self-learning and self-development during the module and after that. The Journal consists of several sections: personal skills audit, learning styles, personal development log, and personal development action plan.

Students are invited to fill in the questionnaire, to analyse the results and comment on them. Completing the questionnaire and analysing the results helps students to identify the strengths and the weakness of their dominant or strongest style and to work toward developing more balanced style.

The data analysis shows that more than 80% of the students have an activist learning style. It is understandable having in mind the requirements of the domain of business and the expectations to students studying in the Faculty of Business studies. The immediate effect of these findings should not be the idea that the learning environment has to take into account only the specifics of the activist learning style. It is hardly expectable that these results would be repeated in other university settings. In addition if the task is designing user-centred learning environment that means the learning preferences of the other 20 % should be taken into account as well as. What could be defined as a more important fact were the comments of students on the questionnaire findings comparing the results and the description of the learning styles. Almost all of them confirm that the questionnaire reflected adequately their learning preferences. It brings the idea of combining a questionnaire and a description for identifying learning styles. The second promising insight was that students would like to develop their weak learning style characteristics.

The learning style questionnaire of Honey and Mumford (1992) was administered at the beginning of the course Web-based Training for MSc students in the Faculty of Educational Science and Technology at University of Twente. During the interviews for the evaluation of the course, the students noticed that the results of the questionnaire could not be generalised for all situations and tasks. This finding supported the idea of instability of personal constructs across the situations and tasks. The practical implication for designing the learning environment of the tool supporting solving design problems is implicit identification of the learning styles by accommodating them in the learning environment. In the tool under consideration this idea is realised by the opportunity students to select a learning event and thus to define their learning preferences.

3.4 Summary

This chapter identified and promoted some ideas that could be beneficial for designing an interactive learning environment of a tool supporting problem solving in educational and training design situations. The ideas might be formulated in the following ways:

- The concept of the individualisation could be operationalised by the notions of learning locus of control, learning styles and level of prior knowledge. An interactive learning environment should propose to users options that vary from a selection of well-structured content to a choice of constructing their own learning content based on a pool of resources. There might be two ways of matching content to learning styles: adaptation and accommodation. Learning styles could be identified in advance and then content adapts to learning preferences. The second approach requires learners to select from incorporated in the learning environment set of learning styles. Users should be able to identify their level of prior knowledge and to select options.

- An interactive learning environment should provide opportunities not only for adapting but also for developing flexibility and versatility of learning styles of users supporting strong stylistic characteristics and compensating deficiencies.
- Issues were identified related to the large number, diversity, and multi-layers structure of individual constructs, instability of personal characteristics over time, space and task, and one-side development of personal preferences.
- Four learning events were identified across different instructional approaches: explanation, examples, procedures and practice. They could be considered as stages of the general learning cycle. People develop preferences to one or two of these learning events. The learning events may become a basis for identifying learning styles of people.
- It seems important to develop in learning environment some functions for monitoring, coaching and providing feedback to users' behaviour.

Chapter 4. Mental mapping approaches

This chapter reports on different mapping techniques such as concept mapping, mind mapping, cognitive mapping, process mapping, causal mapping, hexagon mapping, flowscaping and information mapping. Each of them is considered within a conceptual framework including definitions, theoretical framework, procedures, examples and software. The software examples are evaluated according to its potential to support the main functions playing an important role in all stages of the process of solving design problems. A set of four criteria is established based on the extent to which concept mapping software supports knowledge *elicitation*, knowledge *reflection*, knowledge *representation* and knowledge *creation* (See Section 2.8). The presentation of mapping approaches begins with Concept mapping, probably the most popular mapping technique in the educational domain (Section 4.1), followed by Mind mapping (Section 4.2) and Cognitive mapping (Section 4.3). Than the attention is directed toward the System dynamics mapping (Section 4.4), Hexagon mapping (Section 4.5), Flowscaping (Section 4.6) and Process mapping (Section 4.7). Some specific mapping approaches as Information mapping (Section 4.8), Concept system (Section 4.9.), Axon Idea Processor (Section 4.10) and The Brain (Section 4.11) are discussed as well. In addition some attention is paid also to Site Maps (Section 4.12). For all discussed mapping approaches some information about their origin is given. A set of definitions of different types is presented. Then the theoretical background is discussed. Further, the general procedure for making a map is introduced and it is concluded with an overview of concept mapping software.

4.1 Concept mapping

The idea of concept mapping appeared in the world of education in early 1970s as a result of the efforts of researchers to identify what children know about a particular subject matter domain. Traditional tests failed to explain the extent to which students had understood learning material. The clinical interview method of Piaget (1977) proved to be more reliable, but technically it was very difficult to analyse transcripts and to recognize some patterns that could explain what and how much students had learned or had failed to learn. It has been suggested that interview transcripts would have had to be analysed for the concepts and propositions given by students (Novak, 1998).

Most of the applications of concept mapping are realised in the education domain. Concept mapping reportedly has been used mostly as a graphical advanced organizer and evaluation technique in teaching and as a learning aid for students to organize their declarative, procedural and structural knowledge (Jonassen, Beissner, & Yacci, 1993; Willerman & Harg, 1991). From one side, concept mapping represents the logical structure of a particular subject matter domain. From another side, it represents the psychological structure in which the student assimilates this content. Concept mapping has been used also to capture the perceptions and attitudes of teachers and students towards particular school issues (Novak, 1998).

More recently, concept mapping has found a good reception in business world. The technique has began to be used in a variety of corporate settings: illustrating internal communication problem; understanding the business in which people are involved, construction of a competency concept map; and capturing, storing, and creating corporate knowledge more effectively and efficiently (Novak, 1998).

4.1.1 Definitions

Different names have been attributed to a concept map. For example, a concept map is a "mental mapping" and "concept webbing"(Trochim, 1997); "knowledge web"(Alhberg, 1993); or a "semantic map" (Lambiote, Dansereau, Cross & S. Reynolds, 1989).

A review of the definitions of concept mapping shows how broad the scope of the technique might be. The definitions could be classified as *formal, comparative, nominal and metaphorical definitions*.

From the perspective of formal logical analysis, on a first very general level, a large variety of terms used to define concept mapping could be identified:

- Concept mapping is a process enabling to layout ideas on any topic. Concept mapping is a strategy in which students explore links between individual concepts (Grant, 1998).
- Concept mapping is a *technique* of graphically representing concepts and their hierarchical interrelationship (Beyerbach, 1988); a *technique* for understanding the relationships between ideas (Hale, 1998); an interactive interview *technique,* providing a shared medium for communication (Zaff, McNeese, Snyder, 1993).
- Concept map is two-dimensional *diagram* (Lambiote, Dansereau, Cross & Reynolds, 1989), or a formalism (Zaff, McNeese & Snyder, 1993).
- Concept mapping is a kind of *epistemic game* (Sherry & Trigg, 1996); a *mindtool* for a formal representation of structural knowledge (Jonassen & Marra, 1998); a *mean* for communicating knowledge (Gaines & Shaw, 1998), external *memory aid* (Zaff, McNeese & Snyder, 1993), schematic *scaffolding* (Hammond, 1998).

The second level of formal logical analysis indicates more concrete specifications – concept mapping is related to *knowledge representation* (Ahlberg, 1993; Beyerbach, 1988; Gaines & Shaw, 1998; Huai, 2000; Jonassen, Reeves, Hong, Harvey & Peters, 1998; Kennedy & McNaught, 1998; Kommers & Lanzing, 1998; Kremer & Gaines, 1998; Lawson, 1994; Novak, 1998; Sherry & Trigg, 1996). The knowledge representation involved is predicated by terms such as: *visual (*Gaines & Shaw, 1998; Novak, 1998*); formal* (Gaines & Shaw, 1998; Jonassen & Marra, 1998); *internal* (Ahlberg, 1993); *external* (Reimann, 1999; Zaff, McNeese & Snyder, 1993); *and graphical* (Beyerbach, 1988). The objects of those representations are:

- The internal cognitive structure (internal concept map): *knowledge - declarative, procedural or structural* (Jonassen & Marra, 1998; Novak, 1998; Sherry & Trigg, 1996); *knowledge structure* (Gaines & Shaw, 1998); *conceptual structure* (Hammond, 1997; Jonassen & Marra, 1997); *cognition* (Wandersee, 1990).
- The world or part of it: information (McAleese, 1998; Zaff, McNeese & Snyder, 1993); ideas (Hale, 1998); spatial environment (Ahlberg, 1993); semantic structure (Gaines & Shaw, 1998).

All of the aforementioned formal definitions contribute to the classical consideration of concept mapping. Summarizing them, concept mapping can be defined as *a visual technique applying a specific graphical convention representing either the logical or psychological structure of a particular knowledge domain*.

Apart from those definitions there are some others that present non-traditional views on concept mapping. Concept map is defined *nominally* as a member of families of methods and techniques such as mindtools, research methods and epistemic games.

- Concept mapping is a *research method* among others such as brainstorming, brainwriting, nominal group techniques, focus group, affinity mapping, Delphi technique, facet theory, and qualitative text analysis (Trochim, 1997).
- Concept mapping is a mindtool along with databases, microworlds, spreadsheets, semantic networks, expert systems, multimedia construction, computer mediated communication, and programming language (Jonassen & Marra, 1998).
- Concept mapping is a kind of epistemic game (Sherry & Trigg, 1996). There are three types of epistemic games: structural analysis games, functional analysis games and process analysis games. Structural analysis games include making a list, creating a time line, drawing a map, and filling in a matrix. Some examples of functional games are hierarchical charts and causal-chain diagrams. Process analysis games include among

others program flowcharts, graphical illustrations of the change in a system over time, and spreadsheets to project business profits.

A *comparison* with techniques that are similar to concept mapping can give some more clarification about the essentials of concept mapping. Tables, graphs, and flowcharts, which also can be defined as representational systems, share some of the characteristics of a concept map especially incorporating abbreviated verbal information. However, each of those representational systems allows only limited richness when they show relationships between concepts. They do not apply nonlinear spatial layouts. Concept maps capitalize on the advantages of graphical representations without losing the flexibility and power of natural language system (Lambiote, Dansereau, Cross & Reynolds, 1989).

Some *metaphors* may contribute to defining the core characteristics of concept mapping as well. Concepts in concept map are like *islands* and the links between nodes are described as *bridges* (Ahlberg, 1993). A Road-map metaphor presents concepts as *cities* and the links between nodes as *roads*. The strength of associations is represented by the distance between cities (Vilberg, 1997). Concept mapping is cartography of cognition (Wandersee, 1990). Once mapped a personal experience is not longer considered as terra incognita, but it becomes terra cognita.

A taxonomy of the psychological functions supported by concept mapping could be built up. Concept mapping is recognized as a cognitive aid for the following constructs: perception (Kremer & Gaines, 1998; Novak & Gowin, 1984); memory (Ahlberg, 1993); understanding (Hale, 1998; Novak & Gowin, 1984; Novak, 1998); problem solving (Reimann, 1999); meta-cognition (Jonassen & Marra, 1998; McAleese, 1998); and attitudes (McCabe, 1998).

As it could be expected definitions of concept mapping gave only a general impression of the technique was. A definition basically is not a precise logical figure. However, definitions provide a natural introduction to the more substantial and detailed analysis of the principles underlying concept mapping. Section 1.2 ‘Theoretical framework’ presents some theories that constitute the background of concept mapping. They should give more clarification about the purposes, structure and the procedures of the approach.

4.1.2 Theoretical framework

This section starts (Section 4.1.2.1) by discussing assimilation theory (Ausubel, Novak & Hanesian, 1978), which is considered among the researchers of concept mapping as its theoretical basis. Concept mapping is a practical realization of assimilation theory. Then attention focuses on some information-processing models such as the semantic memory model (Quillian, 1988), the ACT* model (Anderson, 1983) and the theory of structural knowledge (Jonassen, Beissner, & Yacci, 1993).

4.1.2.1 Assimilation theory

Assimilation theory is aimed at promoting meaningful learning. Learning becomes meaningful when it occurs in the context of the learner's prior knowledge. In the epigraph to the book "Educational Psychology. A Cognitive View" (Ausubel, Novak & Hanesian, 1978), Ausubel wrote a statement that "If I had to reduce all of educational psychology to just one principal I would say this: The most important single factor influencing learning is what the learner already knows". Ausubel makes distinctions between reception and discovery learning from one side, and rote and meaningful learning from another. Reception and discovery learning might be either rote or meaningful. The essence of meaningful learning is that symbolically expressed ideas are related in a nonarbitrary and substantive (nonverbatum) fashion to what the learners already know. The meaning can be either logical or psychological. Logical meaning refers to the structure of the content that has to be learned. Psychological meaning is a completely idiosyncratic personal experience in knowledge structuring.

Ausubel distinguishes between three basic kinds of meaningful learning - representational learning, concept learning, and propositional learning. Representational learning includes learning activities where a student recognizes a word, or symbol as a label for a particular object or event. In concept learning a label is learned before attributes of object are recognized. The question is to learn not only the label of a particular concept (definitions), but also the meaning of these concepts. The meaning of a particular concept depends on the type and the validity of propositions in regard to other concepts. The meaning of each concept can be defined and described through propositions which identify relationships between concepts. In this perspective, a concept map is an explicit representation of this integrated knowledge network.

In both concept and propositional learning new information is linked or anchored to relevant aspects of an individual's existing cognitive structure. This process is called subsumption. Ausubel believes that knowledge structures are organized hierarchically with more inclusive and general ideas subsuming more detailed concepts. The subsumed concepts are further elaborated and developed through the process of progressive differentiation. Subsumption and progressive differentiation lead to some changes and modifications in the meaning of the concepts. Often new relationships could be established. This phenomenon is described as integrative reconciliation and in a concept map it can be represented by cross-links (Ausubel, Novak, Hanesian, 1978; Novak, 1998).

It can be concluded so far that concept mapping represents knowledge structures as hierarchies realizing the effects of subsumption and differentiation. The meaning of each of the concepts could be defined on the basis of its relationships with other concepts. Thus concept mapping supports learners to activate meaningful learning processes by explicitly relating new information to what they already know. Doing so learners could modify or change completely the meaning of particular concepts. Meaningful learning enhances the transferability of knowledge.

4.1.2.2 Information processing models

Whether stated explicitly or not, some conceptual resemblance between concept mapping and some theoretical models in the classical information-processing paradigm can be detected. The idea of concept mapping seems to be related to the semantic memory model (Quillian, 1988); ACT* theory (Anderson, 1983); and the theory of structural knowledge (Jonassen, Beissner, & Yacci, 1993). These models look similar to concept mapping not only conceptually, but also graphically.

- *A Semantic memory model* is built as a hierarchical network consisting of three components: units, properties and pointers. Units are set of objects represented as nodes of the network. Properties are described by adjectives or verbs. Pointers specify the relations between different units (‘is-a’, ‘has’, ‘can’ etc). Any concept has a number of associated attributes at a given level of the hierarchy.
- McClelland and Rumelhart (1988) demonstrated how their cognitive connectionist model *called Interactive Activation Constraint Nets* (IAC) manifests many of the properties of human conceptual system. In this network, each attribute is presented as a node. Related attributes are grouped into “pools”. The links between nodes within a pool are all inhibitory or negative. If one of these nodes has a high activation, then it will force down the activation of the other nodes.
- Anderson (1983) made in his *ACT* theory* a strong distinction between declarative and procedural knowledge (memory). Declarative memory (knowledge) contains factual knowledge located in semantic networks. It consists of nodes and links that are labelled. Procedural memory (knowledge) is the knowledge of how to do things. The key component of procedural memory is the production rule. It consists of a set of conditions and an action (if…then). In a problem situation the events from outside are encoded and placed in working memory. Relevant information is retrieved from declarative memory. When an item is activated in declarative memory, the activation spreads throughout the propositional network. Production rules are selected through a process of pattern

matching. If information in working memory matches a production rule condition, then the production rule will be executed. The performance occurs when information in working memory is translated into action.

- According to the *Theory of Knowledge Organization* structural knowledge mediates the translation of declarative into procedural knowledge and facilitates the application of procedural knowledge. If declarative knowledge is *know that* and procedural knowledge is *know how*, structural knowledge is to *know why* (Jonassen, Beissner & Yacci, 1993). Structural knowledge is known also as cognitive structure or pattern of relationships among concepts in memory. Structural knowledge is the awareness and understanding of one's cognitive structure. Structural knowledge is referred to internal connectivity, integrative understanding, or conceptual knowledge. Conceptual knowledge is the integrated storage of meaningful dimensions. The underlying assumption of these conceptions is that the meaning of any concept or construct is implicit in the pattern of its relationships to other concepts or constructs. Structural knowledge as cognitive structure or knowledge structure is a hypothetical construct. Such constructs can be made explicit using different techniques. Concept mapping is reported as the most effective and efficient amongst them. Concept mapping is defined as explicit method of conveying structural knowledge.

The theoretical assumptions and principles of concept mapping are operationalized in procedures for practicing the techniques. In Section 1.3 'Procedure' a step-by-step approach for making concept map is presented.

4.1.3 Procedure

This section lists the steps of the general approach (Novak, 1998) of how to build a concept map. There are some modifications but basically this can be defined as the classic of concept mapping:

1. Identify a focus question that addresses the problem, the issue, or knowledge domain. Identify 10 to 20 concepts that are pertinent to the question.
2. Begin to build your map by placing the most inclusive, most general concept (s) at the top. Usually there will be only one, two, or three most general concepts at the top of the map.
3. Select two, three, or four concepts under each general concept. Avoid placing more than three or four concepts under any other concept. If there are more than five concepts that belong under a major concept or sub-concept create another level of hierarchy.

4. Connect the concepts by lines. Label the lines with one or few linking words. The linking words should define the relationships between the two concepts so it reads as a valid statement or proposition.
5. Rework the structure of the map, which may include adding, subtracting, or changing superordinate concepts.
6. Look for cross-links between concepts in different sections of the map and label these lines.
7. Specific examples of concepts can be attached to the concept labels.
8. Concept maps could be made in many different forms for the same set of concepts. There is no one way to draw a concept map.

The procedure for creating concept maps can be applied in a traditional pen-and paper way or using a specific software tool. Software makes the process of making concept map more effective, efficient, aesthetic and quick. In the following section two examples of software for concept mapping are overviewed.

4.1.4 Software

Two software tools are going to be analysed in this section: *Inspiration*® (Section 4.1.4.1) and *CMap* (Section 4.1.4.2). Inspiration® is considered as the most popular software for concept mapping. *CMap* was released recently. It was developed under leadership of Novak, one of the most prominent writers on concept mapping.

4.1.4.1 Inspiration®

Inspiration® applies concept mapping as a visual learning technique. Visual learning techniques are defined in the Web site of Inspiration® (http://www.inspiration.com/) as graphical ways of working with ideas and presenting information. Visual learning techniques help students to clarify thinking, reinforce understanding, integrate new knowledge, and identify misconceptions. Figure 2 shows a concept mapping made with Inspiration®

Inspiration® provides users with some handy tools affording *knowledge elicitation*. Those are as follows:

- Two types of tools for creating symbols. The tools can add and connect ideas in any direction.
- Rapid fire™. Rapid Fire can generate ideas quickly. The advantage of using the Rapid Fire tool is that users can concentrate on adding the ideas rather than creating symbols

one at a time. Each symbol users add is automatically linked to the idea symbol the users started with.

- Point & type option. To add an idea symbol quickly, users can point to the place on map where they want to add the idea and begin typing. Inspiration® pops a symbol shape around idea to hold the text.

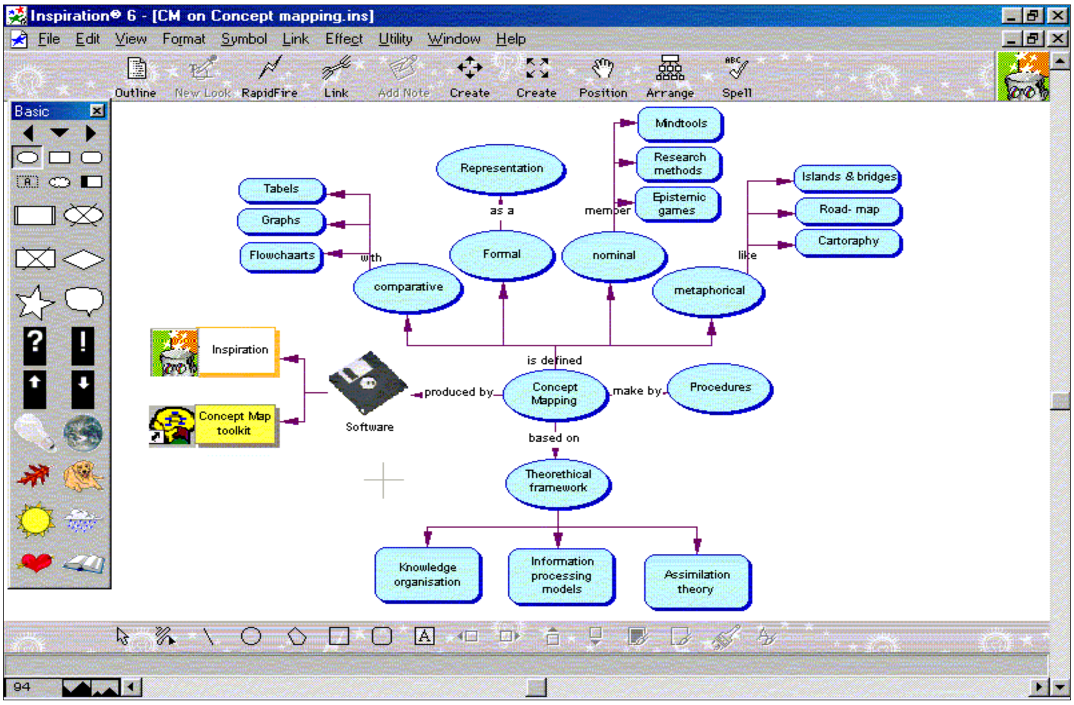


Figure 2.Concept map on concept mapping made with Inspiration®

Inspiration® has some options available to support *knowledge representation* functions. They are as follows:

- The opportunity to use different shape, colours, patterns and thickness of the boundaries of the symbols and to change them.
- Different possibilities for creating links. There is a special tool for drawing links. Users can make a link simply by dragging. The type, direction, thickness, line pattern, and colour of links can be changed easily. Inspiration® supports another important component of concept mapping graphical conventions – attaching labels to the links. Each time a link is drawn, a text box appears along the link.
- Symbol Palette. The library of Symbol Palette proposes 18 topics containing more than 400 specific symbols.
- Fine tuning symbols – aligning symbols, spacing symbols evenly, positioning symbols precisely, making the symbols the same size, adjusting the map for page breaks.

- Hierarchical multilayer options presenting map details on different levels of detail.

Inspiration® supports *knowledge reflection* and analysis. Some of the functions for knowledge reflection are as follows:

- Outline view to keep track of work on ideas.
- Magnifying and reducing the view. Users can zoom out in order to see more of maps or outline in the window. If users want to make symbols or topics look bigger, they could zoom in. They can also zoom in or out to a specific percentage.
- Hiding part of map. Users may want to isolate an idea or concept so they can develop it more completely. To do that, it is helpful to show only that portion of diagram while users are working on it. They can also hide subsymbols for a symbol in order to see just the higher level view of the map.
- Reading text in a reduced format. To make it easy to read the text in a large map, a magnified version of the text appears in the Status bar.
- Using drawing tools to make clusters.
- Show levels which identify the levels of hierarchical organisation of nodes.
- Arrange symbols according to types of diagram (top-down tree, bottom up tree, cluster, left tree, right tree, web)
- Show checklist. Checklist tracks progress of users. They can check off topics in Outline view or symbols in Diagram view.
- Attach notes to the symbols and allow formatting of the text and changing colour.

Inspiration® has some *knowledge creating* opportunities. They are listed as follows:

- Pictures and graphics in symbol galleries can be used to provoke creating unconventional ideas.
- Create own symbol library. Users can create their own symbol libraries for graphics they could import or create using the draw tools. They can also copy the symbols they use frequently into a custom symbol library.
- Moving symbols. The simplest way to move symbols around on a map is to click and drag them. A group of symbols can be marked and then together moved in another direction.
- Changing direction of a link.

All of the options listed above fit perfectly for knowledge representation, but are not designed purposefully to support knowledge elicitation, knowledge reflection and knowledge creation. It could be done if those functions are not left to users to discover but an appropriate support is attached to *Inspiration*®. The functions have a dreaming potential and a triggering mechanism is needed to activate them in a relevant way. For example, *Rapid Fire* is very useful option whose potential could not be used fully with support such as 'quick drawing of symbols'. There *should be* a support explaining what it is, when, where, how and why to use it. *Rapid Fire* is a nice tool for visual brainstorming but without the user knowing the principles and rules of brainstorming its potential for knowledge elicitation is limited. Using a particular picture might be powerful technique for idea generation, but again support for how to introduce a picture, in what context are, what guidelines to follow is needed very important. Drawing tools can become useful clustering tools if a support is provided. Otherwise they will always remain only drawing tools.

The help system of Inspiration® supports only the graphical functions of the tool, not the concept mapping method itself. The option 'Template' might be considered as a small exception. There are 34 templates, most of them supporting learning and teaching. Some of the templates are about different thinking functions such as comparison, classification, analogy and idea generation. Users can create their own templates. 'Template' is a useful option that goes beyond the traditional support for only graphical functions of the software. However 'Template' supports mostly the learning events of examples and demonstrations, and maybe practice. Background information and procedures are underestimated. Users are left to derive themselves the principles of making particular types of maps and how to do it.

4.1.4.2 Concept Map Toolkit (CMap)

The Concept mapping toolkit – CMap (2000) is developed under the leadership of Novak at the Institute of Human and Machine Cognition of the University of Western Florida (http://cmap.coginst.uwf.edu/). The tool supports users to create and share knowledge models represented as concept maps. The toolkit also allows users to collaborate with colleagues in the construction of concept maps anywhere in a local and global network. Basically the tool fits very well with the classical convention of concept mapping. Nodes, links and labels can be created easy. Figure 3 shows a concept map made with CMap.

CMap has some functions that support *knowledge elicitation*:

- The CMap tool proposes a very flexible and intuitive way of creating nodes (clicking the left mouse button twice) links (just dragging from a node). Dragging a link from a concept creates automatically a new concept and label on the link. The tool allows drawing a link from a link, which is a unique function.

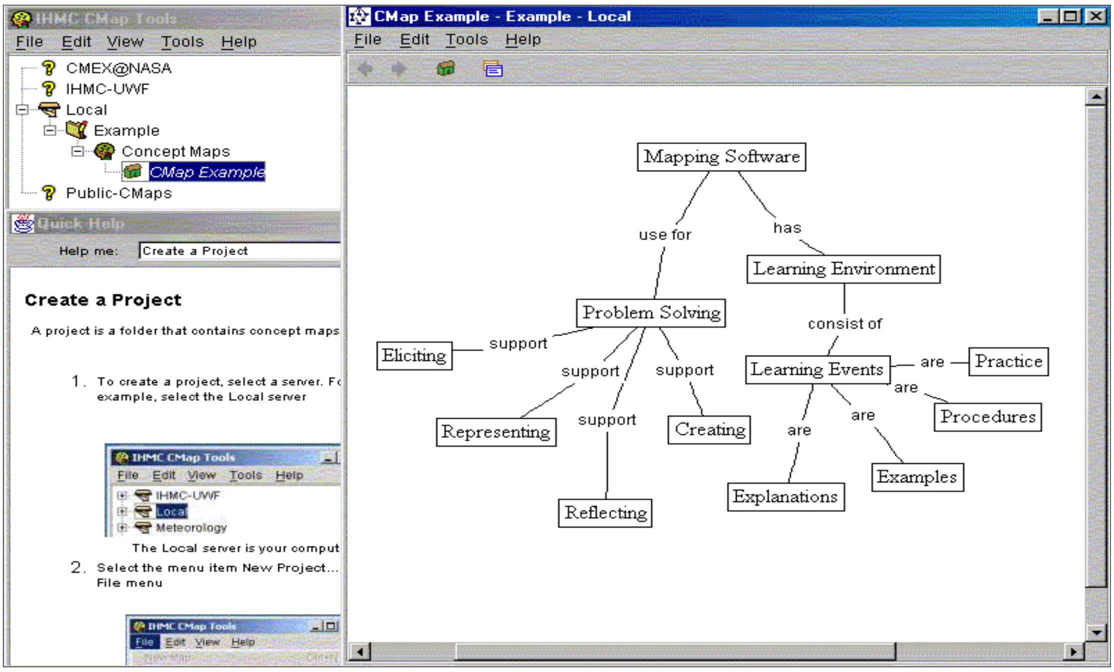


Figure 3. Concept map on mapping software made with CMap®.

The features of CMap for *knowledge representation* are as follows:

- Editing attributes of nodes: font name, font size, font colour, background colour, border colour, and border types.

There is one function for *knowledge reflection*:

- A navigation tool providing an overview of a map.

CMap can support *knowledge creation* with the following functions:

- Resources can be attached to each node. They might be images, text, sound, URLs and even other concept maps. The tool makes available a concept map pool where different subjects are interpreted as concept maps.
- The tool supports collaboration between different users for sharing and exchanging ideas.

The classification of CMap functions under the categories of knowledge elicitation, representation, reflection and creation seems artificial. It is because CMap is designed to apply strictly the original concept of concept mapping as a knowledge representation.

4.2 Mind mapping

T. Buzan (Buzan & Buzan, 1996) developed mind mapping technique in an attempt to optimise the process of receiving, remembering, and restructuring information. He was not happy with the traditional styles of note taking/making. All of these styles apply three types of tools: linear patterning (notes written in straight lines); symbols (letters, words and numbers); and analysis (its quality affected by linearity). Buzan and Buzan (1996) found that standard note taking overlooks other tools that our mind makes available: visual rhythm, visual pattern, colour, image, visualization, dimension, spatial awareness, gestalt (wholeness), and association.

Some findings in the domain of psychology of learning and especially remembering (not left/right brain theory) lead Buzan (Buzan & Buzan, 1996) to the idea of mind mapping. They noticed that in the learning process human mind remembers the following:

- Items from the beginning of learning period (‘the primacy effect’)
- Items from the end of learning period (‘the recency effects’)
- Any items *associated* with patterns already established
- Any items which are emphasized as being in some way unique
- Those items that are in particular interest to the person
- Any items that appeal strongly to any of the five senses

Buzan (Buzan & Buzan, 1996) noticed that in his own lecture notes on the psychology of learning (which were traditionally linear) the concepts of association and emphasis were missing. Thus he arrived to the idea of mind mapping. Mind mapping has a very large spectrum of applications: mnemonic device, creative thinking, self-analysis, solving personal problems, making diary, story telling, preparing lecture notes, chairing meeting, presentations, and counselling. The following sections provides definition (Section 4.2.1), discusses the theoretical framework of mind mapping (Section 4.2.2), describes the procedure for mind mapping (4.2.3) and presents the Mind Manager - software for mind mapping (Section 4.2.4).

4.2.1 Definition

Mind mapping was defined as an external manifestation of the way our mind organizes information. The technique has four main characteristics:

- The subject of attention is crystallized in a central image.
- The main themes of the subject radiate from the central image as branches.

- Branches comprise a key image or key word printed on an associated line. Topics of lesser importance are also represented as branches attached to higher level branches.
- The branches form a connected nodal structure (Buzan & Buzan, 1996, p.59).

4.2.2 Theoretical framework

There are four theoretical sources provoking the insights for the development of mind mapping: radiant thinking theory, brain hemispheres mental ability support, information processing, and the history of human intelligence.

- According to *radiant thinking* theory, every bit of information that our mind receives can be represented as a central node from which radiate many hooks (tens, hundreds thousands, millions according to Buzan and Buzan). Each hook is an association and each association has its own branches. Radiant thinking refers to associative processes that proceed from or connect to a central point. Radiant thinking reflects the internal structure and processes of mind. Related to this, mind mapping is an external mirror of radiant thinking.
- The second theoretical source for mind mapping is the scientific finding that the *two hemispheres* of the brain cortex tend to divide the major intellectual functions between them. The right hemisphere supports the intellectual functions of rhythm, spatial awareness, whole picture, imagination, daydreaming, colours and dimension. The left hemisphere is dominant in the mental skills of words, logic, numbers, sequence, linearity, analysis and lists. In addition to that it was found that both hemispheres while being dominant in certain activities, are skilled in all areas (Buzan & Buzan, 1996, p. 33). Buzan and Buzan (1996) refer to some so called ‘Great Brains’ such as Leonardo da Vinci, Picasso, and Einstein to emphases that they used more effectively than their peers the wide range of their mental skills.
- Some insights have been taken from research in the domain of *information processing*. The human mind has five major psychological functions: receiving, holding, analysing, outputting and controlling which are mutually beneficial to each other. Receiving is about anything we get from outside. Holding is synonymous with memory, the ability to store and access information. Analysing means pattern recognition and information processing. Outputting is defined as any form of communication or creative act, including thinking. Controlling refers to metacognitive abilities.
- The *history of human intelligence* is another scientific domain that inspires the idea of mind mapping. Buzan and Buzan (1996) claim that different types of externalisations of

internal pictures of human beings had stimulated the very rapid development of human civilization and intelligence.

4.2.3 Procedure

The general procedure of mind mapping is very simple. It includes the following three steps:

- The main issue is put at the middle of the page. It could be word or image.
- The most general concepts, called Basic Ordering Ideas (BOI) radiate from the central theme as branches. They comprise a key word or image printed on associated line.
- Each of the Basic Ordering Ideas is further sub-branched into more concrete concepts.

There are some guidelines about techniques and layouts that could make mind maps more functional and effective (Buzan & Buzan, 1996). They are listed as follows: Techniques (Use emphasis, Always use a central image, Use images throughout your mind map, Use three or more colours per central image, Use dimension in images, Use synaesthesia (the blending of the physical sense), Use variation of size, or printing, line and images, Use organized spacing, Use appropriate spacing, Use associations, Use arrows when you want to make connections within and across the branch pattern, Use colours, Use codes, Be clear, Use only one key word per line, Print all words, Print key words on lines, Make line length equal to word length, Connect lines to other lines, Make the central lines thicker, Make your boundaries 'embrace' your branch outline, Make your images as clear as possible, Keep your printing as upright as possible and Develop a personal style) and Layout (Use hierarchy, and Use numerical order).

The *general procedure* of mind mapping when applied for different purposes takes some modifications. Here more attention will be paid to a mind mapping procedure for creative thinking as far as creative thinking is closely related to the issue of solving design problems. The procedure includes the following steps:

- *Quick fire mind map burst*. Start with drawing a stimulating central image of a subject under consideration. Then radiate from it each idea that comes to mind.
- *First reconstruction and revision*. Make a new map identifying Basic Ordering Ideas, combining and categorizing ideas, build up hierarchies, finding new associations. Similar or even identical ideas in outer boundaries should not be dismissed. They are considered as fundamentally different as far as they belong to different branches. These concepts should be underlined in their second appearance to give them appropriate mental and visual weight. They should be outlined with a geometric shape on their third appearance. If they occur a fourth time, they should be boxed in three-dimensional shapes. Linking

these three-dimensional areas create virtually a new mental framework bringing new insights. It may lead to a radical reorganization of the ideas.

- *Incubation*. It is expected that once a mental set is established then the mind is able to reach a breakthrough of thinking patterns when no longer reflect on map, but in a situation of relaxing, running, and daydreaming.
- *Second reconstruction and revision*. After incubation the mind has a fresher perspective on the first and second maps. It might be useful to do another quick fire mind map burst to consolidate the results from the integration of the first three stages.
- *Search for solution*. This is the final stage where a solution, a decision of realization of the issue should be found.

4.2.4 Software

Mind Manager is the official mind mapping software developed by *Mindjet* (http://www.mindjet.com/) and recognized by Buzan and Buzan (1996). *Mind Manager* (1998) follows completely the graphical convention of mind mapping. The software is defined as a tool for visual thinking. Visual thinking helps in organizing, structuring, creating and presenting ideas. *Mind Manager* is designed to support mainly knowledge representation but it has the potential to support knowledge elicitation, knowledge creation and knowledge reflection. The issue is that this potential has to be realised. The Figure 4 shows an example of a mind map made by *Mind Manager* during one of the experiments (Chapter 8) described in this study.

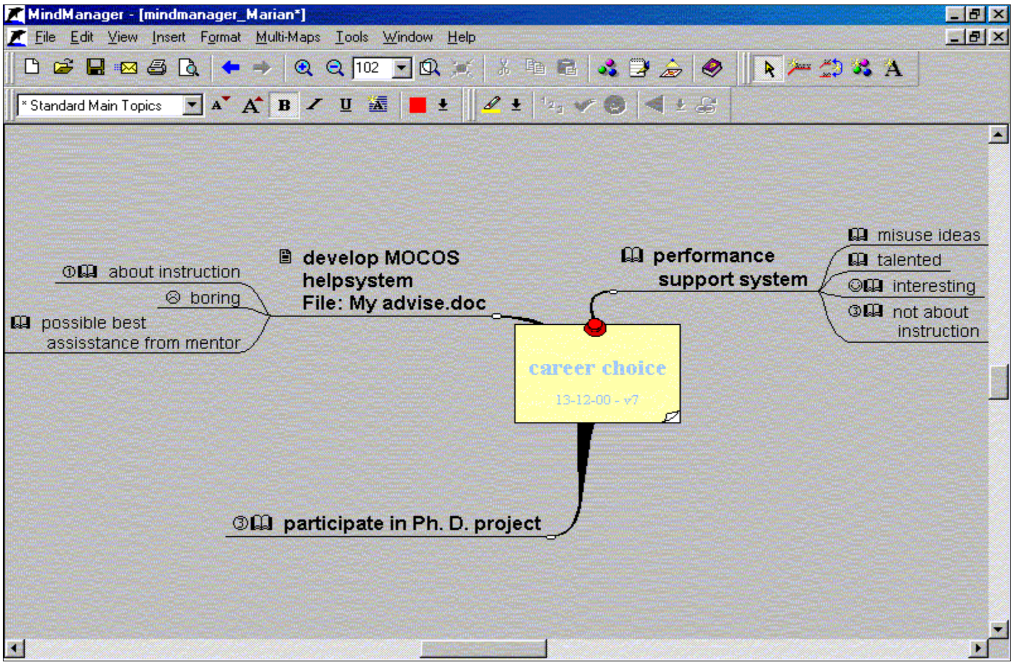


Figure 4. Mind map made with Mind Manager

There are two features of the tool that could be used for knowledge elicitation:

- Brainstorm mode. Ideas appear instantly on the main branches of mind map.
- Insert new branch function. It can be activated by double-clicking anywhere on the map or clicking the 'Insert New Branch' button on main menu. *Mind Manager* supports this function with right button clicking and the 'Insert' key. This applies also for subbranches.

Mind Manager poses the following options for *knowledge representation*:

- Changing colour of branches and sub-branches.
- Highlighting and establishing a boundary over branches
- Adding floating text
- Adding text notes
- Showing relationships between branches
- Attaching priorities to branches
- Regulating spacing between branches and thus avoiding overlapping by layout option
- Using the symbol gallery which contains 27 topics
- Creating multi-maps connected with internal hyperlinks between maps.
- Cycling through maps via workbook mode.

Mind manager support *knowledge reflection and analysis* with the following features**:**

- Focus on branches - displays all sub-branches of a particular branch, and closes all other main branches to basic level.
- Levels of details - allows choosing the level of detail to display for an entire map or a particular branch.
- Overview window option for single and multi-maps to cope with large map.
- Rearranging, sorting and numbering branches
- Attaching specific symbols of priority
- Drawing cross-branches

Mind manager supports *knowledge creation* with the following functions:

- Brainstorming mode can be use for idea generation as well.

- The symbols in the library can be used as a stimulus for creative thinking. For example, picking randomly one or few picture from library could facilitate the creative problem solving techniques such as 'connecting the unconnected 'and' picture portfolio'.

The learning environment of *Mind Manager*, called Help Centre, proposes several options: Quick tour, Tutorials, Sample maps, On line help, Tips and Tricks and Keyboard shortcuts. The main learning events the centre supports are examples with 'Sample maps' and procedures with 'Tutorials'. The previous version of Mind manager (3.5) had a learning-by-doing option. It could be assumed that the options in the Help Centre might support people having different learning preferences although it does not seem enough apparent for users. Figure 5 shows the Learning Centre of the *Mind Manager*.

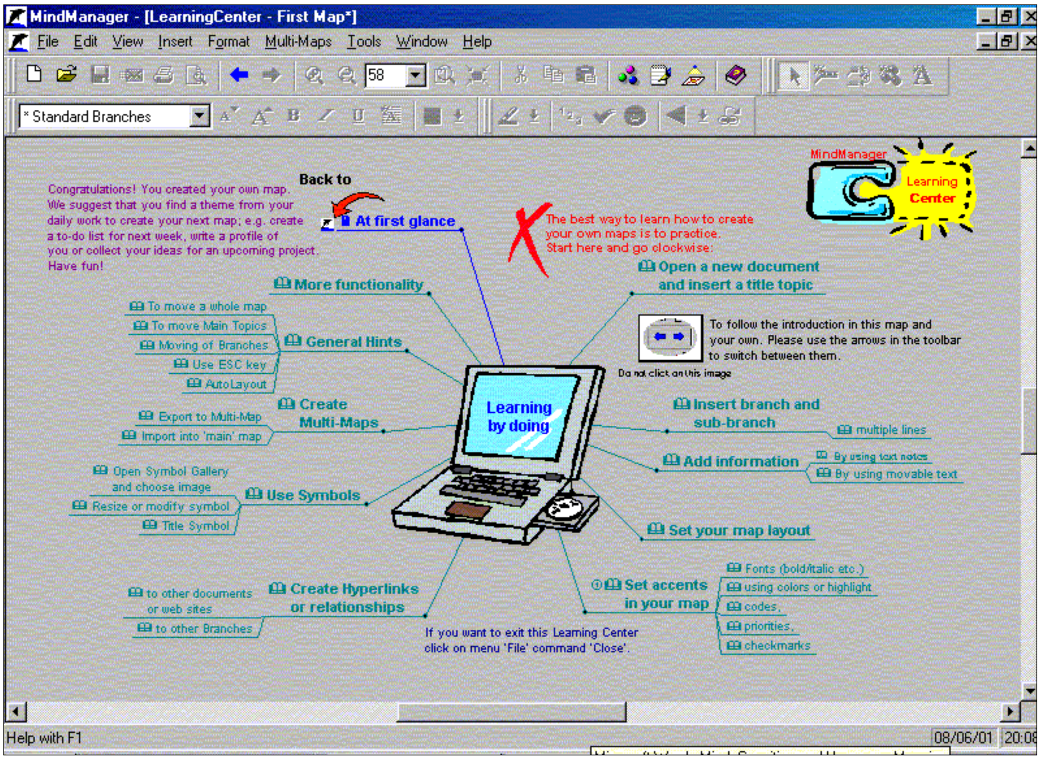


Figure 5. The Mind Manager Learning Centre

It should be emphasised that all of the options of the Help Centre are designed primarily to support Mind manager as graphical editor. There are few sentences about the mind mapping method. However there is a progress when comparing the latest version of Mind Manager 4.0 with the older version of the tool. 'On line help' in the heading 'Learn the Basis' offers the general procedure for drawing a mind map. One of the sample maps 'How to create mind maps' proposes guidelines for making a mind map.

4.3 Cognitive mapping

The development of cognitive mapping is attributed to a group of researchers around Eden (Eden, Ackerman, & Cropper, 1997). They have been applying operational research methodology to deal with complex and messy problems in strategic management. The team have realized that using formal methods to model problem situations was not effective enough. It turned out that not modelling problems but identifying the problem and problem structuring seemed to be crucial issues. The team adopted a new ‘soft’ approach taking insight from Kelly’s Personal Construct Theory (Kelly, 1955 cited in Eden at al., 1997) and started to use repertory grid technique which is practical application of the theory. However soon they found that the technique was not friendly and transparent enough to the clients. In addition, they realized that visual representation of the information seemed to be very important in communication with clients. Thus Eden and his colleagues came to the idea of cognitive mapping that could provide an elegant way of eliciting, analysing and communicating the personal construct systems of clients in ill-structured situations. The structure of this section includes definition of cognitive mapping (Section 4.3.1), Theoretical framework of cognitive mapping (Section 4.3.2), Procedure for cognitive mapping (Section 4.3.3) and Software (Section 4.3.4).

4.3.1 Definition

Cognitive mapping aims at producing a representation of how a client thinks about a particular issue. It helps clients to grasp their thoughts, understand the assumptions about certain issues, and to determine if is necessary to change their minds. The technique applies a specific procedure for capturing the client’s perception of complex situations. Mostly the technique was used as note-taking method during an interview or to set an agenda for an interview with a client. Cognitive maps could provide valuable clues of the client’s perception of the problem giving indications where main issues lie, what are the goals and objectives, what should be the means for accomplishing these goals, which feedback loops can be identified and how the conflict can be explored.

4.3.2 Theoretical framework

The interpretation of Kelly’s Personal Construct Theory (1955) was reported as the underlying theoretical rational of cognitive mapping (Eden, Ackerman & Groper, 1997). Three issues triggered the attention of Kelly as clinical psychologist stimulating him to develop his theory (Stewart, 2000). They are as follows:

- The need to look with precision at people as individuals. Research on masses of people even when it leads to producing some scientific laws does not allow making a precise predictions about individuals.
- The need to avoid observer bias. People tend to see an environment in the way they expect to see it. This is called ‘observer bias’ and it could prevent one to understand properly other people’s views and to interpret events.
- The need to acknowledge that people are able to take responsibility for their own development and they do not need an expert to tell them what to do. Most adults are enough matured and intelligent to know what their problems are. As the popular sentence said, ‘if you want to know what is wrong with someone, ask him, he probably knows’ (Stewart, 2000). A facilitator is to help a client to understand what is the problem and to stimulate him or her to undertake the necessary steps to solve it.

The basic assumption of Kelly can be expressed, as ‘Man is Scientist’. An individual creates, tests, modifies or rejects hypotheses based on his or her unique experience. The hypotheses not only reflect the experience of the person but they also influence experience and condition it. Kelly used the term ‘construct system’ to name the set of hypotheses a person could develop. The meaning of the notion ‘construct system’ is twofold: something that is constructed from experience and something through which we can construct and interpret experience. If a facilitator understands the construct system of someone else the facilitator can make some predictions about how he or she is likely to behave in a given situation.

Kelly’s theory of personality, which is evolved from the basic notion of ‘man-as-scientist’, can be summarized as:

- Perceptions influence expectations and expectations influence perceptions.
- The mechanism that mediates these processes is known as a construct system.
- Construct systems are unique to individual and develop through life.

In addition to his theory, Kelly developed a specific technique, called ‘Repertory Grid’ to capture the personal construct systems of people. The main categories of the repertory grid technique are elements and constructs. Elements are pieces of information that constitute the issue under consideration. The constructs are elicited from the element on the basis of a simple rule. Three of the elements are taken in various combinations and a question is asked how two of them are similar to each other and different to the third. Thus bipolar constructs are created. According to Kelly, bipolar constructs are the only way to understand the meaning of something. Bipolarity gives a sense of context. The same element in different construct systems can be expressed as different pairs of constructs.

An important concept in the repertory grid technique is 'laddering'. A construct system is a hierarchy with some constructs more substantial for a person and other more marginal. A way of picturing this in repertory grid is a series of interlocking ladders, getting smaller in number and stronger in influence/strength as one reaches the top. People can go to the top asking series of questions 'why' to determine the consequences of constructs and they can go down asking series of questions 'how' to find exploratory constructs. Guidelines for how to transform the theoretical principles of Personal Construct Theory and practical rules of repertory grid into a cognitive mapping approach are presented in the next section 'Procedure for Cognitive Mapping'

4.3.3 Procedure

Ackerman, Eden and Cropper (1997) distinguish three general principles of applying the cognitive mapping technique:

- The problem is broken into its continuing elements – usually phrases of 10-12 words each. They should retain the language of problem owner.
- Each concept should be presented as a bipolar construct. The meaning of a concept is retained through the contrast between both poles.
- The phrases are linked by arrows to form a hierarchy of means and ends. Different layers can be identified in the hierarchy.

The steps in the procedure for making a cognitive map should be perceived just as rules-of-thumb not as compulsory rules to follow:

- Break the problem description into phrases of 10-12 words each.
- Identify the concept according to the criteria of three layers: Goals, Strategic Directions (key issues), and Potential Options
- Build up a hierarchy of three layers. Goals should be placed on the top of map, strategic directions (key issues) should be put into middle layers and potential options should be placed on the bottom.
- Look for goals. They are usually broad statements and are considered by problem owner as 'good things per se'. Because goals are not stated explicitly they have to be extracted from a document or elicited from client. A useful technique for that is asking a series of questions 'why' until client is not able to differentiate further.

- Watch out for strategic directions. They should support achievement of the goals. Strategic directions often form a flat hierarchy themselves but would be linked to goals and potential options.
- Watch out for 'potential options'. They are described as a portfolio of means supporting strategic directions. Asking series of questions 'how' prior to key issues could derive potential options.
- Look for opposite poles. Each concept should be expressed in bipolar format giving psychological contrast that clarifies the meaning of the concept.
- Place the concepts in imperative form. Where is possible include actors and actions. Through this action perspective, the model becomes more dynamic.
- Keep the language of the problem owner. Try to avoid abbreviating.
- Make links between concepts to mark chains of reasoning. Identify the option and outcome within each pair of concepts. Each concept could be seen as an option leading to a superordinate concept which in turn is the desired outcome of the subordinate concept.

4.3.4 Software

Decision Explorer (2000, http://www.banxia.com/demain.html) was originally designed to support cognitive mapping approach. It is defined is a tool for capturing, analysing and structuring ideas. Decision Explorer applies the core set of principles of personal construct theory and repertory grid technique.

Figure 6 shows a cognitive map made by *Decision Explorer* – software for cognitive mapping. *Decision Explorer* might support *knowledge elicitation* with two functions:

- Rapid entry mode – a quick drawing of a set of constructs.
- Double click option for creating constricts.

Decision Explorer has very elaborated tools for *reflecting and analysing*. The main types of analysis are as follows:

- Hierarchical analysis. Hierarchical sets in cognitive map helps in identifying layers of goals, strategies and options.
- Potent analysis. Potent analysis shows the idea in the bottom of the map that feeds in to many key issues. This is the most 'potent' idea. It leads to many ideas in higher layers. The elements with highest potency scores affect many key issues. The 'potent' idea suggests actions.

- Cluster analysis is based on the density of the linking between thoughts. It assembles the closely linked ideas into groups. Based on this analysis a further differentiation of the cluster is possible, to add further elaboration and to re-analyse the model.
- Collapse analysis. It allows 'hiding' details and seeing a global overview of the map or any part of it.
- Exploring concept. Gives an overview of the relationships with other concepts.
- 'View' option. *Decision Explorer* provides up to 32 views of a map. Each view has a map display mode and text display mode.
- 'Listing'. This option gives the opportunity for listing all concepts, heads, tails, or sets.

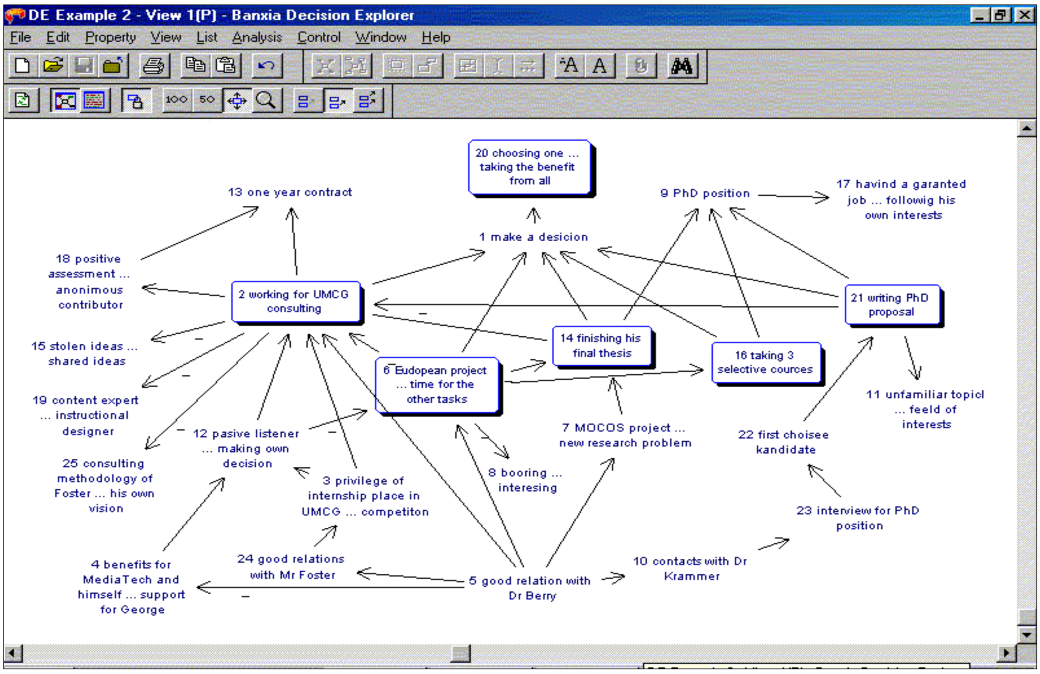


Figure 6. A cognitive map made with Decision Explorer

Decision Explorer can support *knowledge representation* via:

- Drawing nodes – just double clicking on the free space
- Connecting nodes – dragging from one nodes to another
- Styles. Define or change the style of concepts depending on their function in the map – whether they are goals, key issues or options.
- Map option. Choices about the format of the map – hierarchical options (banded, fanned, outward fan, inward fan) and tree options (left, right, top, bottom)
- Formatting concepts. Font, size and colour of the letters can be defined or changed.

The learning environment of *Decision Explorer* provides support for both the graphical editor of the tool and for making a cognitive map. The learning environment of the software consists of a traditional help system for supporting skills in making nodes, links and other graphical attributes, and conducting analyses of a map. An interactive tutorial shows how a cognitive map could be made. From the Web site of the software (http://www.banxia.com/demain.html) papers that can be downloaded to explain the process of making cognitive maps. It could be assumed roughly that the learning environment of *Decision Explorer* includes the learning events of background information with the articles in the Web sites, examples with the Introductory Tutorial, procedures with the Help System and a paper in Web site, and stimulates practice with the opportunity for downloading the trial version of the software.

4.4 System dynamic mapping

System mapping is known in its two forms: system dynamic mapping and causal mapping. System dynamics was developed in later 1950s by Forester at Massachusetts Institute of Technology (Vennix, 1997). Based on the analogy of management with electrical engineering, Forester studied management decision making from the point of view of an information feedback control system. System dynamics tried to distinguish itself from an operational research approach to management. Operational research dominant at that time was supposed to support managerial decision-making by applying some formal methods. However it failed to be effective in solving non-linear and open-ended strategic managerial problems. Dynamic mapping supports analysing and exploring the implicit models people build about ill-structured situations. Playing with these models and simulating different options in a safety environment could bring more deep insight in understating of those situations. The section introduces to the definitions of system dynamic mapping (4.4.1), theoretical framework (4.4.2), procedure (4.4.3) and software (4.4.5).

4.4.1 Definitions

In a contrast with concept mapping, dynamic mapping is homogenous in its definitions. People using this paradigm share the same understanding about the process, structures and theoretical principles of dynamic mapping. Dynamic mapping builds a model of a system and conducts some experiments in order to understand better the behaviour of the system. There are two types of dynamic mapping - flow and causal. The causal form of dynamic mapping deals mostly with the structure of a system while the dynamic form is concerned with processes.

Causal mapping can model a real causal system in a way that helps to understand and analyse their underlying mechanisms and structures (Laukkanen, 1998). Causal maps can be used to present the structure of the target system and the critical interrelationships between its components. For the technique it does not matter if the causal relationships concern personal cognitive constructs or established valid objective relationships. The key is that the target is a system of variables which have or are assumed to have causal connections.

Jenkins (1998) distinguishes between four types of causal map methodologies: self-Q technique, means-end chain method, construct grid and comparative causal mapping.

- *Self-Q methodology* focuses on the elicitation part of the process rather than on the analysis of the mapping activity. This methodology consists of four stages: collection of concepts, verification of these concepts, identification of causal links between them, and verification of the map by asking questions to respondents. This approach while facilitating the elicitation of very idiosyncratic concepts in a relatively unstructured way, imposes a structure through a ranking which focuses respondents on the issues that are most relevant to a particular research question. The self-questioning approach is designed to reduce the biases of the interviewing researcher and thus optimising reliability.
- *Means-end chain* method is grounded on a personal grid or as it is called a triadic sort technique. The technique is purposed to minimize the influence of the interviewer on the respondent when eliciting data. The triadic sort elicits constructs that are later laddered. The interviewer can identify which are pools and why respondent prefers a particular pole of construct. These data are transformed as a matrix of all constructs, which are then aggregated to produce a hierarchical value map.
- *Construct grid* is designed to be used as an interactive tool assisting in clarifying problems and facilitating group solutions to complex issues. It allows display and analysis of causal maps. Some researchers find this to be similar to cognitive mapping (Eden & Ackerman, 1998)
- *Comparative causal mapping* is an approach for comparing causal maps across respondents. The researcher conducts interview with respondents and codes all the data, which are then incorporated into maps. The process involves an unstructured interview based on a pre-established protocol, which is intended to identify the causal patterns that respondents use when making sense of complex situations.

This section so far gave a short overview on the origins of system dynamic mapping and some definitions. The next section presents the theoretical background of system dynamic mapping.

4.4.2 Theoretical framework

In this section several theoretical perspectives are going to be reviewed. System dynamic (Section 4.4.2.1) is a theoretical paradigm considered as a basis for research and practice on system dynamic mapping. In addition the cognitive psychology concepts of mental models (4.4.2.2) and information processing (4.4.2.3) traditionally are linked to the dynamic mapping approach.

4.4.2.1 System dynamic

System dynamics is a theory related to the structure and behaviour of complex systems. There are four hierarchical levels of system structure: closed boundary; feedback loop; levels and rates; and discrepancy between actual and desired goals and conditions (Vennix, 1997). '*Closed boundary*' means that all components and relationships that are considered important for explaining the behaviour of a system should be included in a system dynamics model. The behaviour of the system is self-organized and depends mostly on interactions between components of the system in the format of feedback loops inside the closed boundary. *Feedback* is the key concept in dynamic mapping. It could be seen is a process where action and information in turn affect each other. There are two types of feedback loops: positive and negative. The dynamic characteristics of systems are determined by the interaction between positive and negative feedback of the system. The *discrepancy* between actual and desired conditions of a particular system state requires actions that activate feedback loops. Any feedback loop in a system dynamic model contains at least one *level* (stock). Levels are the accumulations in a system.

Thinking about a situation in system terms and feedback processes could change perception before implementation of the results takes place. Visualization of complex situations via series of feedback loops can help people to increase their information processing capabilities. Feedback processes support people to express their understandings of situations more accurately.

4.4.2.2 Mental models

The concept of mental model (Hayes-Roth & Hayes-Roth, 1988; Norman, 1993; Schank, & Abelson, 1988, Venix, 1997) in the frame of references of dynamic mapping means descriptions, interpretations and explanations of situations which the individual perceives. Mental models are constructed by selecting and interpreting information from the environment. The selection is based on already formed mental models. People create mental models for reality which in turn determine their behaviour (Vennix, 1997). System dynamic researchers call this phenomena 'self-fulfilling prophecy'. Reality is not a passive image in the mind of people. They construct reality according to their mental models and information coming outside. Because people have of different mental models, one of the most important goals in structuring messy problems is the creation of a shared reality and problem definition among the group of problem owners.

4.4.2.3 Information processing

The dynamic mapping paradigm reflects some of the breakdowns in the ways people process information. Most of the problems in this respect are due to the limited information processing capacity of the human mind. Basically, people are able to hold in working memory no more than '7 ± 2' unrelated chunks of information (Miller, 1956, cited in Benjafield, 1996). Problem solvers tend to reduce complexity in order to prevent cognitive overload when ill-structured situation occurs. They pay more attention to the parts of a system rather than on the system as whole. Because of that problem solvers develop a narrow view on a problem. Problems are prematurely defined, the search for information is incomplete and is terminated when a satisfactory solution appears. This is not an optimal solution according to the system dynamic paradigm.

4.4.2.4 Learning taxonomy

The learning taxonomy of system dynamic mapping consists of the following levels: assimilating content, gaining understanding, building understanding, building the capacity for building understanding, and building capacity for sharing understanding (Human Performance System, 2000). Assimilating content and gaining understanding are characterized as the most prevalent but the most ineffective type of learning. In the first type of leaning the emphasis is on content' facts, in the second – on the relationships between content units. Both 'assimilating content and gaining understanding' are described as passive types of learning. Students absorb content or assimilate someone else's understanding. Building understanding is a constructivistic learning. Students actively explore content and construct their own knowledge. Building the capacity for building understanding is about developing a generic system of thinking skills that goes beyond any concrete content. Building a capacity for shared understanding reflects the ability to share one's understanding with others. Sharing understanding and opening opportunities for others to re-create understanding for themselves is a way for gaining deeper insight into content.

The researchers on dynamic mapping noticed especially the learning effects of the approach (Lane, 1994; Vennix, 1997). They define model building by dynamic mapping as a learning process. Most ideas about ill-structured situations are gained during the iterative processes of dynamic mapping rather than when the model is completed. In relation to the idea that dynamic mapping could enhance learning, Lane (1997) proposed an approach he called 'modelling as learning'. One of the first tasks to accomplish in this process is to convince clients to joint the process of model building via dynamic mapping. It is important also to capture and to express the implicit models that clients have about a particular situation. Mental models reflect the client's perception on how a complex situation works and can help him or her to make sense of this situation. Capturing mental models helps to understand what the client thinks about a situation and if it necessary to change this perception which literally is defined as learning. The 'Modelling as learning' approach provides clients with different learning environments accelerating the process of learning by experience. Clients can 'play' with their mental models as 'transitional objects'. They could arrive at better understanding of the situation, modify it or even change it. Changing some parts of the model and seeing the effects of that can be done by risk-free experimentation. Another benefit of 'modelling as learning' is the opportunity to express explicitly the ideas of a client's implicit model. Dynamic mapping helps in revealing the complexity and wholeness of a given situation not only part of it. The 'Modelling as learning' approach applies some techniques such as brainstorming, metaphors and analogies, scenarios, and SWOT analysis, and some tools such as causal-loop diagrams, magnetic hexagons, STELLA (2000) and *Decision Explorer* (2000) software tools.

Dynamic mapping reflects the theoretical principles outlined in the section about theoretical background of the approach. They could be recognized in the practice of dynamic mapping. The following section 4.4.3 'Procedure' transforms the theoretical principles in some guidelines for making dynamic maps.

4.4.3 Procedure

The ideal detailed procedure of dynamic mapping consists of five stages, which are as follows:

- *Problem identification and model purpose* (Define time horizon, Identify reference modes, Define level of aggregation, and Define system boundaries)
- *System conceptualisation* (Establish relevant variables, Determine important stocks and flows, Map relationships between variables, Identify feedback loops, and Generate dynamic hypotheses)
- *Model formulation and parameter estimation* (Develop mathematical equations, Quantify models parameters, Analysis of model behaviour, Check model for logical values, Conduct sensitivity analysis, and Validate model)

- *Policy analysis* (Conduct policy experiments and Evaluate policy experiment)
- Model use or implementation

Usually practice requires some modifications of this procedure. Vennix (1997) in the framework of a policy-making project applied a procedure of dynamic mapping that included the following four phases:

- Problem statement
- Preliminary conceptual model (map)
- Knowledge elicitation cycles (Questionnaire; Workbook; Structured workshops)
- Final conceptual model

The process is cyclic, not linear. Iterations and movement forth and back are possible. The starting point of system dynamic mapping is a *problem* considered from a system point of view. The purpose of this first step in dynamic mapping is to understand better the problem and the potential effects of actions. In this stage the gap between actual and desired problem conditions is identified. The gap can be sketched over time and is called ‘reference mode of behaviour’.

The Preliminary conceptual model or system conceptualisation establishes the boundaries of the system, which determines what is considered to belong to the system and what is not. The next step in conceptualisation is visual representation of the system or modelling behaviour of the system. Two types of visualizations are used: causal loop diagram and flow diagram. The purpose of modelling is to find feedback loops that underlie the problem.

The *elicitation* activities of a project group produced a preliminary model of the problem. The second step was to apply the Delphi technique to support group discussion on this preliminary model. The Delphi method included three cycles. In the first one, the project group prepared a questionnaire including a number of sections each presenting a particular issue. The second cycle of the Delphi method used a so called ‘workbook’, which was based on the results of the questionnaire. The workbook presented to the participants four sub-models in the format of causal diagrams. They were based on the preliminary model and the results from the questionnaire. The third cycle, workshop, included small group and panel session discussions. In another project Vennix (1997) kept the procedure almost the same with two exceptions. He used the Nominal group technique for knowledge elicitation instead of the Delphi method and for modelling he combined causal diagram with hexagon mapping. More details about hexagon mapping are given in section 4.5 in this chapter.

4.4.4 Software

The most familiar software tool for dynamic mapping is STELLA® (2000). It is a production of *MM High Performance Systems, Inc, The System Thinking Company™* (http://www.hps-inc.com). The purpose of STELLA software is to increase the effectiveness of rendering mental models, simulating the model to producing dynamic outputs, analysing the outputs to understand what causing them, and communicating mental models to others (Human Performance System, 2000). Learning to construct mental models that better reflect the reality and learning to simulate them more reliably is described as vital to making world works more effectively. The aim of STELLA is to accelerate and enrich these learning processes. The Figure 4.6 presents the basic interface of STELLA. The four main building blocks are 'stock', 'flow pipe', 'connector' and 'converter'. Stock represents phenomenon that accumulates, contains number of things, or defines quantity.

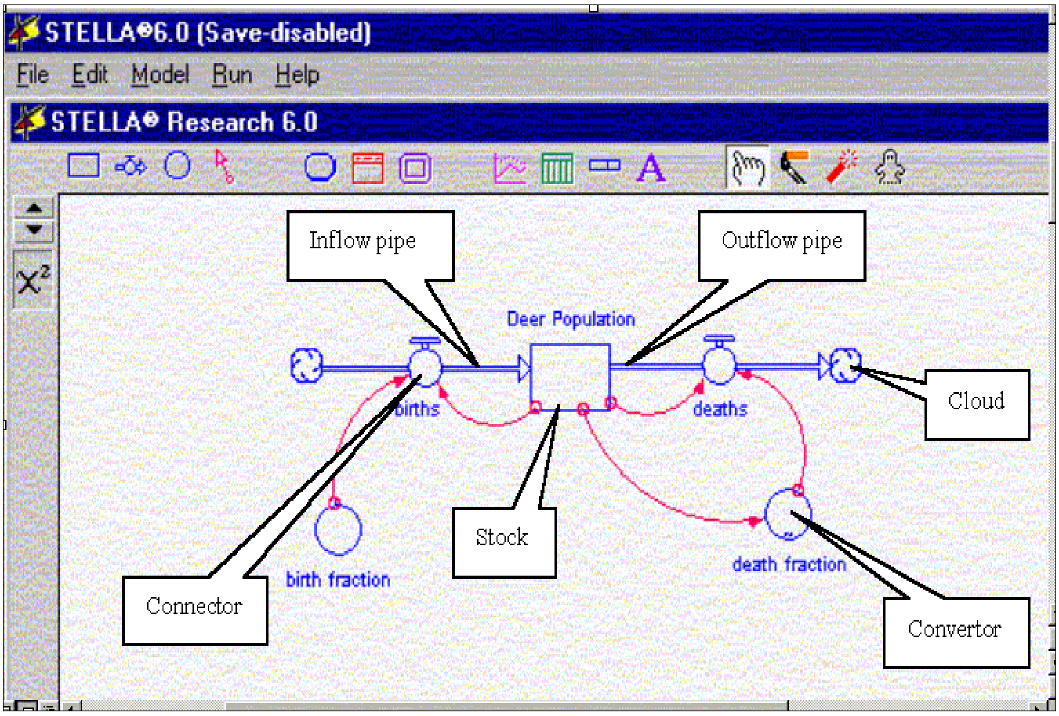


Figure 7. Basic interface of STELLA

For example, population, knowledge and fears accumulate. The software applies a specific simple graphical convention. Dynamic mapping always starts with a stock. In the example that comes with the software (Figure 7), deer population is a stock. Then a flow can be added to a stock. For example 'births'. In the case under consideration 'births' are an inflow to deer population. 'Deaths' are an outflow of the model. Clouds are the boundaries of situation. In the language of STELLA software 'stocks' are 'conditions', 'how the things are', while 'flows' represent 'actions' or 'how the things are going'. Connectors are used to show the relationships between components of the model. 'Converter' gives a direction of reducing the gap between actual and desired conditions of situation. It contributes to the inflow variables in order to change the actual conditions represented by stock.

Basically, the functionality of STELLA supports four types of activities: mapping, numerating, simulating, and communicating. The software requires values to be given to the variables and allows parameters to be changed. The system generates equations based on the model.

The function in STELLA that allows the user to pick an icon ('stock', 'flow' 'converter' or 'connector') and post it in working space facilitates *knowledge elicitation*. Simulations of models which can be run based upon computations which the system executes support *knowledge representation*. The results of simulations are visualized by availability of some graph options. STELLA also proposes some valuable tools for *analysing* the results of simulation such as 'Sensitivity Analysis and 'Graphical Functions'. STELLA is very much a knowledge *creation* tool because it constructs and tests models.

One of the most powerful, attractive, and unique characteristics of STELLA is embedded in the tool opportunity for *sharing* models with other people. STELLA can build an interactive learning experience that lets people discover the insights that the creator of a model has uncovered. Essentially it is an authoring tool for multimedia presentations. The author of the model can build a learning environment for introducing the results of his or her exploration. Buttons can be drawn and navigation functions can be attributed to them. Apart from text, pictures, sounds and video can be assigned as well as to the learning environment in a very intuitive way. Users can explore the model and can conduct experiments with the data.

The learning environment of STELLA is based on the principles of problem-based learning, discovery learning and role-playing. The Web site of the software provides a library containing cases related to different subject matter domains: life sciences, social sciences, physics, mathematics and engineering, and humanities. For example one of the cases in the social science domain confronts users with an immigration problem on the borders of Mexico and USA. A user is challenged to take the role of immigration adviser to the president of USA. Background information is available, a model can be explored and simulations can be run.

4.5 Hexagon mapping

Hexagon mapping was developed by Hodgson (1999). Sometimes the author calls it 'concept mapping by hexagons', other time – 'cognitive mapping by hexagons'. Hodgson likes to point out the similarity between dynamic mapping and hexagon mapping. Some of the researchers in the dynamic mapping paradigm use hexagon mapping for eliciting mental models (Vennix, 1997). '*Decision Explorer*', the software for cognitive mapping, in its saving option can creates an additional hexagon mapping file. However, in this study hexagon mapping will be considered as a specific type of mapping because it applies a different metaphor, it has a unique theoretical basis and a distinct practice. This section reports on definition of the hexagon mapping (Section 4.5.1), theoretical framework of hexagon mapping (Section 4.5.2), procedure of hexagon mapping (Section 4.5.3), and hexagon mapping software (Section 4.5.4).

4.5.1 Definition

Hexagon mapping is a part of the visual facilitation approach, which combines dynamic representation with creativity. It is a type of modelling using visual idea representing units, called idons (a composed word of 'icon' and 'idea'). Icons take the form of hexagons. Idons afford manipulating, combining and rearranging as a continuous process of formulating thoughts (Hodgson, 1999). Idons are seen as powerful tools for representing the process of building mental models. The hexagon mapping supports expressing communicable mental work-in-progress in ill-structured situations. Hexagon method using magnetic hard objects on a whiteboard or icons of software tool "stands in relation to thinking as a brick does to building" (Hodgson, 1999). It is simple and modular. Idons take the function of transitional objects which one can play with to help modelling a problem solving situation. The transitional toolkit plays the same role for the adult mind as learning toys can do for the child's mind. It is a kind of conceptual Lego kit.

4.5.2 Theoretical framework

Hexagon mapping accepts some of the basic theoretical assumptions of system dynamic mapping (Vennix, 1997) and the principles of lateral thinking (De Bono, 1990). From the dynamic mapping paradigm it adopted the idea of modelling and sharing internal perceptions of a situation, and the concept of transitional objects. From the lateral thinking paradigm it took the idea of characteristics of pattering system and techniques for provoking the breakthrough of dominant thinking patterns. In summary the basic principles of lateral thinking used in hexagon mapping are as follows:

- Recognition of dominant ideas
- The search for different ways of looking at things
- The use of chance and provocative methods in order to change patterns

Hexagon mapping provokes a strategy for creative thinking that become popular as 'Connecting Unconnected'. The notebooks of Leonardo da Vinci, Samuel Morse, James Watt, Einstein, Sigmund Freud, and Goethe are evidence that they have used this strategy to come up with their great ideas (Michalko, 1991, 1998). 'Connecting Unconnected' forces a connection between two different subjects. It is based upon the principle that when a person makes a connection between two unrelated subjects the imagination will leap to fill the gaps in order to make sense of it. The hexagon template 'Four-Fold Generator', the 'Oblique Thoughts' 'Shuffling functions', and the Brainstorm mode of the *Idons-for-Thinking* hexagon mapping software support escaping from dominant patterns and provoking the generation of new ideas. The idea of colour coding in hexagon mapping might be considered as an interpretation of the *Six-Thinking Hats* method (De Bono, 1992). The theoretical background of hexagon mapping is concretised in a step-by-step approach, which is a subject of consideration in the Section 4.5.3 'Procedure for hexagon mapping'.

4.5.3 Procedure

The procedure for hexagon mapping includes the following steps:

- *Issue conceptualisation*. Brainstorming the issue of consideration using magnetic hexagons or specific software. Every single idea could be captured as headline on a hexagon. Hexagons initially can be placed randomly.
- *Issue map*. It involves clustering hexagons to remove the initial chaos after brainstorming. The 'issue map' provides a new perception on the problem and a platform for formulating the next step of thinking and decision making.
- *Influence diagramming*. Hexagons can be linked in order to identify possible feedback loops and even further conceptualisation of the model.
- *Generative thinking*. This is the creative step in the hexagon mapping as lateral thinking is stimulated. The unrelated ideas on hexagons are associated randomly in order to evoke a new association. Hexagons can be moved into any paired association chosen in random. The third blank hexagon provokes a lateral idea.
- *Convergence*. A hexagon template for creative convergence stimulates several generations of ideas. Such a template is the co called 'four-fold' generator. It reflects the number of selecting starting ideas. There might be 'eight-fold' or even 'twelve-fold' generators. In the case of 'four-fold' generator, from the brainstorming session and clustering four more interesting and diverse ideas could be selected and then placed in the outer cycle of the template. They are first generation ideas. Second generation ideas are

filed blank hexagons. A third generation idea is the filled blank central hexagon. It is a creative association between ideas of the second generation.

In addition Hodgson suggests colour coding the two-dimensional surface of hexagons. It allows assigning a further layer of significance. Colour coding gives a non-verbal signalling system of the way people perceive a particular situation. Their biases on some aspects of situation could be detached.

4.5.4 Software

Idons-for-Thinking (1999) is the ultimate hexagon mapping software. Figure 8 presents an example of a hexagon map made by *Idons-for-Thinking*. The tool supports *knowledge elicitation* through the following options:

- Brainstorming mode. It allows users to create idons very quickly.
- Library of idons. Idons with different forms, callouts, dilemma idons and block arrows can be picked up by mouse and then drop over the models surface.
- Converting text files to idons. The program scans each paragraph of the file and converts it into an idon containing that paragraph.

Idons-for-Thinking support *knowledge reflecting* with the following options:

- Clustering. There are special forms to drag around idons. Automatic numbering in a cluster will renumber all objects in a cluster (beginning at Number 1) according to their screen position (top most left most).
- Survey Mode. When Survey Mode is on, all models will be read only. This allows users to view models quickly without fear of making any changes. Users could make changes to a model but the program will not prompt the save function when models are closed.
- Viewing all models. Create an array of images of all models in a specified folder. This can be useful in organizing models or creating a hierarchy of all models.
- Creates links to all models in a folder. It establishes an array of linked idons to all models in a specified folder. Each idon contains a link to a model file and its text will be the file name.

Idons-for-Thinking empowers *knowledge representation* with the following options:

- Model markers. A model marker is a quick reference to a model. The marker stores a small image of the model for easy visualization by user. It is possible to create a marker groups. They contain any number of model markers.

- A set of toolbars that help to present the ideas in most attractive and flexible way. They are the arrow toolbar, block arrow toolbar, callout toolbar, cluster toolbar, dilemma toolbar, idon toolbar, and color palette.

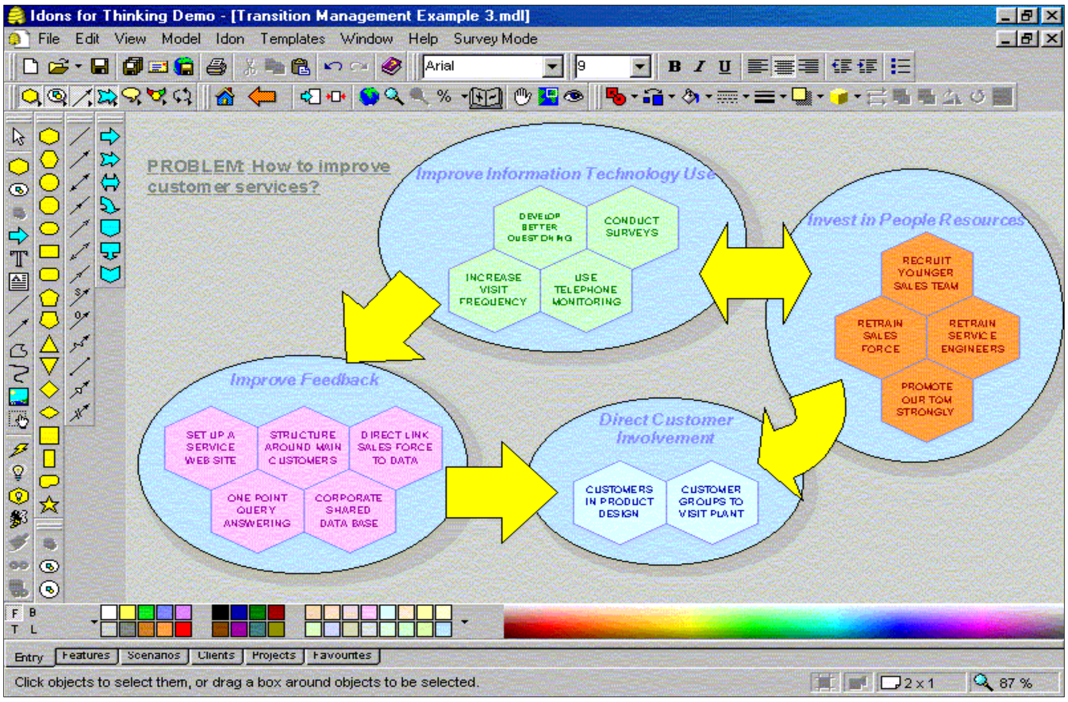


Figure 8. Hexagon map on problem solving made with Idons-for-Thinking

Idons-for-Thinking is designed to support *knowledge creation* with the following functions:

- Templates. Several templates are available to facilitate different thinking strategies in modelling situations. Some of them are generators (four-fold, eight fold and sixteen fold), scenarios, options, and priorities.
- Shuffling. Randomly shuffling could stimulate different combination of idons that could provoke the generation of new ideas.
- Oblique thoughts. These are sentences taken from different sources that are supposed to inspire thinking. A user can directly create an idon with a particular oblique thought.
- Gateways. A Gateway is an idon or object that is linked. Gateways can be linked to any file on hard drive, network, Intranet or Internet. The file can be anything: a model, program, sound, animation, or document.

The learning environment of *Idon-for-Thinking* proposes a traditional help system for different functions of the tool, templates and some articles about hexagon mapping. Templates and articles support hexagon mapping approach, while help system supports graphical editor of the tool.

4.6 Flowscaping

Flowscaping is a type of mapping approach based upon the concepts of 'water logic' and 'flowscape' (De Bono, 1994). Flowscape is composed word created from the terms of 'landscape' and 'flow'. Section 4.6.1 gives a definition of flowscaping. Section 4.6.2 describes the theoretical framework of the approach. Section 4.6.3 provides the procedure for making a flowscape.

4.6.1 Definition

De Bono uses the metaphor of a map of a landscape in order to define 'flowscape'. A flowscape is a map of our inner landscape. It represents our perception as it is at the moment. We make a flowscape in order to understand our perception about a particular situation. With flowscape in front of us we can see both sensitive and important points in our perceptions. We can focus attention on the most critical factors and to decide what interventions to undertake.

Flowscape involves looking at the flow. 'Flow' is the main concept of water logic, a term De Bono (1994) uses to distinguishes between two types of logic: traditional 'rock' logic and 'water' logic that applies the principles of lateral thinking. Rock logic is based on 'is'. Water logic is based on 'to' – what does it flow to? what does it lead to? what happens next? how we can use something? Traditional rock logic is based on identity – 'this is', and on 'have' and 'inclusion'. Water logic emphases the importance of context. A truth is very often a truth only in a certain context. More details about fundamentals of water logic and mechanisms of forming perception are given in the next section - 'Theoretical framework of flowscaping'.

4.6.2 Theoretical framework

According to De Bono (1990), the human mind is a self-organizing system. Self-organizing systems are pattern creating and pattern using systems. They have some distinctive characteristics that define the way our mind handle information and the way we proceed with this information. The mind provides an environment for incoming information to organize itself in patterns. To make it easier to understand what a self-organizing system is, De Bono provides two metaphoric examples in which he presents two basic models for organizing information. These are 'towel' and 'gelatine' models. In order to reproduce exactly what De Bono means by self-organizing system, the two experiments is going to be described. The 'towel' experiment is as follows:

> "Take a white towel and lay it out on a flat surface. From the bowl of blue ink, take a spoonful at a time and pour it on to the towel at any place. The towel represents a recording or memory surface. The ink represents the *input* to the surface. The ink stain represents the

> *record of memory* of that input. After a time, the towel will be covered with an array of blue spots which will represents the complete record of all the information that has come onto that surface. The crucial point is that the record will be *exact*. The absorbent nature of the towel will ensure that the ink *stays exactly where it is put*. Surface will be a passive record of all the information that has come in. The time at which the information arrived will make no differences (De Bono, 1990, pp. 15-16).
>
> The second experiment involves a large flat dish of gelatine. The procedure is exactly as previous except this time heat the bowl of ink. The spot where the spoonful is poured and the sequence of spots can be exactly the same as for the towel. While the ink is hot it dissolves away some of the gelatine. After a few moments, the cooled ink and the melted gelatine are poured off the dish. What is left is shallow depression in the surface of gelatine. This is the record or memory of where the ink was placed. If the link is poured onto the surface just next to an already existing depression, then the hot ink will flow into that depression, making it ever deeper. After a while this erosion will result in channels, just as a landscape is eroded by rainfall into streams and rivers. The significant point is that the ink no longer stays where it is placed but flows away along a channel to a new place. Furthermore, as the ink flows along a channel it deepens that channel even more, thus making it increasingly likely to divert further incoming information. The gelatine surface does not actually organize the information but it provides an environment for the information to organize itself into patterns. The patterns are the channels in the surface. Information arriving at one part of the channel flows along to the end of the channel. The gelatine surface is an information processing system because you usually get more than you put it. This is because the ink placed at one spot actually gets to flow through several other spots as well as. In the gelatine example *time* is very important variable. The sequence in which the different spots on gelatine surface receive the spoonfuls of ink will totally determine the way channels form." (De Bono, 1990, p. 17).

The concepts of water logic and flow are based on the physiological study of brain nerve activities, whose substantial characteristic is that one state always flows to another. The nerve circuits constitute a system in which one state of activity is followed by another. Usually states are unstable and all drain into a stable repeating loop. This is because the brain as a self-organizing system is an active system and each input always ends up with a stable loop. This is the way perceptions are formed. All other single inputs are unstable and are just intermediate effects. In perception effects always flow to a stable pattern. This mechanism can explain some of the basic behaviours of perception such as recognizing, centring, and preparedness. Once the stable pattern is established, in terms of pathway preferences, then any input, which is at all similar, will be recognized. Centring is our ability always to recognize a general concept that subsumes examples. Preparedness means that mind can see only what it is prepare to see.

Sometimes a self-organizing system stabilizes itself into more than one loop. It means that the world could be seen, for example, in two ways. If two perceptions occur simultaneously then, for a variety of reasons (more flashy memory or tracks or emotions) one of them will be more dominant and will lead to a 'shift of attention'. One of the most difficult things is changing perception via enlarging of a loop or even more challenging - shifting between loops. If a person is happy with a stability of a loop then it will be extremely difficult for him to change it. It does not matter that the loop might be not completely relevant. From one side, the dominance and the stability of a loop are two very important characteristics underlying perception. From another side, they might have a 'premature closure' detrimental effect in problem solving when a rather narrow, stereotypic and sometimes inadequate perception is applied to situation. The theoretical framework of flowscaping sounds rather complicated. According to De Bono it is not necessary to understand everything. People may practice flowscaping without understanding everything about the theoretical fundamentals of flowscaping. The section 4.6.3.Procedure provides with some practical guidelines how to make a flowscape. Figure 9 shows an example of a flowscape.

4.6.3 Procedure

According to De Bono the procedure for making a flowscape consists of the following steps:

- *Stream of consciousness list*. It includes the ideas that occur when considering a situation. They might be aspects, ideas, items, features and factors related to situation. Put down them in a list each point on a separate line.
- *Alphabetical order*. Go through the list and give each item a letter from alphabet as an indicator.
- *Flow*. Take the items on the list one at a time and indicate to which another item it leads. It is not matter of cause and effect but 'what comes to mind next', or what is the closest association to an item.
- *Flowscape*. Connect the letters with arrows according to the logic established in previous step. Each letter has to be put only once on the flowscape. Each letter has to have a single arrow going from it to another letter.
- *Tidying up*. The first flowscape will look messy. It has to be redrawn in a neater way.
- *Analysis*. Flowscape when is ready needs to be examined like a landscape. We should look at three features at least: connectors, stable loops and links. Collectors are points, which seem to attract to them many other points. They are maybe the main causes of an issue. Collector points are possible action points. Every flowscape should contain at least

one stable loop. If a loop cannot be identified, it means that something is wrong with the flowscape. Each of the points in the feedback loop can be examined for possible solutions. Links are points connecting collectors and stable feedback loops. They can possibly indicate a weakness of the position and stimulate thinking to generate options for overcoming it.

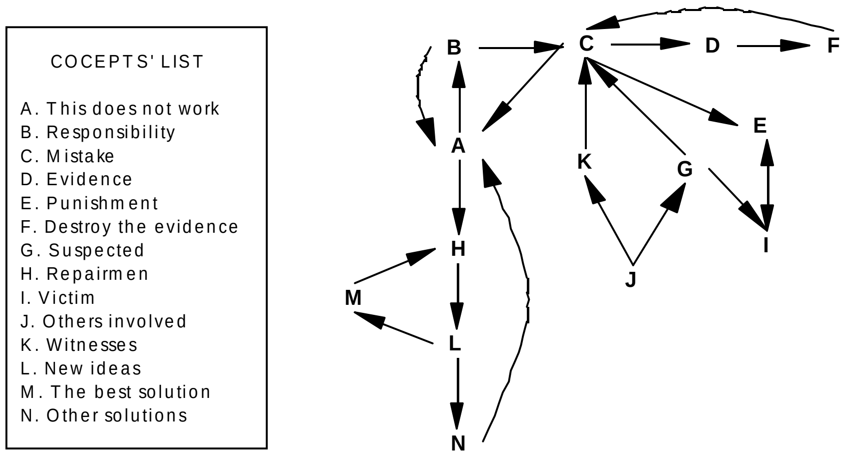


Figure 9. A flowscape on how to approach problems with a sense of humour

There is no specific software for flowscaping. Any graphical editor can be used for making a flowscape. The procedure for flowscape supports knowledge elicitation, knowledge reflection, and knowledge representation. It might sound strange, but flowscape does not support knowledge creation although it has been always related to the lateral thinking methodology. Lateral thinking is synonymous with creative and ‘out of box’ solutions. Flowscape helps mainly in identifying what is a problem and what are the causes of that problem. Generating solutions to a problem is left for the later stage and other lateral thinking techniques are supposed to be used.

4.7 Process mapping

Process mapping is a management tool initially developed and implemented by General Electric as an integration of their ‘*Work Out*’ and ‘Best Practices’ approaches. *Work-Out* is a modelled problem solving process, whose objective is to improve productivity while streamlining the company's slow, decision making process. *Work-Out* combines three days of off-site discussion about organisational problems and then the bosses get proposals for improving the business processes (Garvin, 2000). *Best Practices* is another initiative aimed at grasping the implicit and explicit expertise of the employees in the company.

Process mapping has been used to describe in workflow diagrams and supporting text, every important steps in business process. General Electric process mapping strategy has helped management and business reengineering teams to understand what happened, to eliminate ineffective and inefficient processes, and to implement a new process-driven structure. While this technique is mostly used in a business environment, it could be applied to analyse the processes in any kind of organisation, including educational. Organisational processes are universal phenomenon. They share some common characteristics.

The introduction to process mapping will be kept close to its original definitions (Section 4.7.1) and theoretical framework (Section 4.7.2). The procedure for process mapping (Section 4.7.3) is going to be interpreted in the light of its possible use in the process of solving educational and training problems. The principles of process mapping could be applied in the solution implementation phase of the process of solving design problems.

4.7.1 Definition

Process mapping is defined as a methodology that provides tools for identifying current 'As-Is' business process and can be used to make a 'To-Be' roadmap for reengineering product and services. Process mapping supports better understanding and improving business process and bottom line performance (Hunt, 1998). A lot of valuable information about product and services can be obtained by studying the relationships between inputs and outputs. However understanding of what really is happening is problematic if there is not knowledge about the processes between inputs and outputs. Any kind of working process consists of series of stages. Some of them can be identified with a single function, but most of the processes are cross-functional. Each step of the process adds a value to the next step. Process mapping increases the understanding of business processes by breaking them into sub-processes, workflow elements, service processes, and manufacturing processes.

4.7.2 Theoretical framework

Process mapping is based on the concept of structured analysis, which proved to bring some valuable ideas in diverse business applications such as banking, insurance, auto and aerospace industries, and pharmaceuticals. Process mapping takes into account three basic variables: process goals, process design, and process management. Each process contributes to one or several business goals and it should be measured according to extent to which organizational and individual performances are achieved. Process goals are derived from three sources: business enterprise goals, customer requirements, and benchmarking information. Process design refers to establishing an effective and efficient structure of a process in order to accomplish the goals. 'As-Is' analysis of the processes is needed to identify the current state-of-art of existing process. Based on identification of the gaps and problematic spots, a 'To-Be' process map is generated in order to improve or even change business process. Process management includes four elements: process goal management, performance management, resource management, and process interface management. Process goal management is concerned with establishing a set of process sub-goals and functional sub-goals. Performance management is about building a system for getting internal and external feedback on the process outputs, tracking process performance against goals and continuously improving process performance, and establishing procedures for solving process problems. Resource management task is to allocate the right resources in the right time and at the right place in order to support achievement of process goals. Each function gets a share of resources, according to its contributions to the process. Process interface management is to visualize the relationships between inputs and outputs in general and to show the points where one process activity provides a deliverable for another process activity.

4.7.3 Procedure

Process mapping begins with an analysis of what the process problem is, separated from how this process problem will be solved. The first step is to represent the whole system process as a single module – a box with arrow interfaces. Then the process map box is expended in more details in another diagram where several boxes are connected with arrows. The boxes represent process map sub-levels. When a process module is broken down into process sub-modules, the interface between the sub-modules are shown as arrows.

If we do not strictly adhered to the originals of process mapping and its definition, then flowcharting and Program Evaluation Review Technique (PERT) or Research Planning Diagram (RPD) can also be classified as types of process maps. They have broad scope of domain applications. The basic procedure is flowcharting. PERT and RPD are elaborated flowchart techniques following specific purposes. A flowchart is a graphical depiction of a sequence of events, which show what happens in a particular situation under all possible circumstances. A flowchart applies a specific graphical convention consisting of circles, rectangles, and diamonds. Circles indicate the beginning and the end of a flowchart. Rectangles contain descriptions of what happens. Arrows show directions of a flowchart. Diamonds indicate decision points as a question is asked and the flow goes in different directions depending on the answer. PERT and RPD diagrams could contribute more relevantly than classical flowchart to a problem solving method. Process mapping might be especially useful for the implementation phase of the method where a plan for putting a solution into practice has to be drawn. The remainder of this section is going to present PERT (Section 4.7.3.1) and EPD (4.7.3.2) in more detail.

4.7.3.1 Program evaluation review technique (PERT)

PERT is a modification of well-known flowcharting technique. A PERT network is a graphical representation of the sequence of activities and events needed to reach an objective. It shows the flow of relationships between activities and events and the order in which they must be accomplished to achieve a project or program's objective.

PERT consists of activities, events, and dummy component. Activities such as designing, constructing, and evaluating consume time or resources. In PERT network, activities are represented by arrows that have a beginning and an ending point. Task descriptions and time estimates usually accompany each arrow in a network. Events are the points where activities begin and end. They consume neither time nor resources and function as transition point between activities. There is no limit to the number of activities that can lead into or out of an event, but each activity must begin and end with an event. A dummy is an activity of zero duration and zero expenditure of resources. It is normally represented by a dashed-line arrow and is used to maintain the logic of network.

The following steps are typical for constructing a PERT network (Van Gundy, 1997):

- Establish and define the project objective. Determine what the end product should be.
- Plan the network. Map all activities needed to achieve the project objective. If necessary the activities could be broken down into sub-activities.
- Construct a basic network. The first step involved in developing a network is to construct a skeleton flowchart depicting the relationships between the events and activities. Activities are numbered according to the sequence in which they need to occur.
- Add details to the basic network. If analysis of the basic network reveals that achievement of objective is likely to be more complex than depicted by the basic network, then more details should be added. This review of the network is important to ensure that no relevant events and activities have been omitted.
- Collect time estimates. A feature that distinguishes PERT from other charting techniques is use of time estimates to predict the duration of each of activities.
- Calculate the expected time. There are two methods for calculating expected time estimates. First, there is a single estimate method, which is simply a prediction of the expected duration of each activity, independent of all other activity. The second method uses three estimates to calculate expected time: optimistic time, pessimistic time and most likely time.
- Calculate the latest allowable time.

The flow of events and activities must be developed according to certain rules:

- An event may not begin until all activities preceding it have been completed.
- An activity that follows an event may not begin until the event has taken place.
- The network of arrows does not represent alternate paths; every line in a network must be used to achieve an objective.
- Each event may occur only once; after an event has taken place, the loop of network activities may not return to it.
- Only one activity may connect any two events. If more than one activity must connect two events, a dummy activity should be used.

4.7.3.2 Research Planning Diagram (RPD)

Research Planning Diagrams (RPDs) are like simple flowcharts in their attempt to grasp activity sequences without many details (Van Gundy, 1997). The construction of RPD contains the following steps:

- State the project objectives, being sure to specify the desired end result.
- List the action needed to complete the project, starting with the first required activity and then listing the remaining activities in their required order of occurrence.
- For each activity list the important questions that must be answered before following activities can begin.
- Using the information in step 2 and 3 begin constructing the diagram, starting with the first required activity and then sequentially listing each subsequent activity and decision point. Use arrows to connect the activities and decision points and to show the flow of action through the diagram. When is necessary time estimates may be assigned to the activities and probability estimates may be assigned to the decision points.
- If a response to a decision point is difficult to determine or presents a major obstacle to project completion, use a "rethink" response.

The procedures of PERT and RPD could be applied effectively and efficiently if an appropriate process mapping software is used. There are two types of process mapping software: general-purposes *iGrafcs Process* and *Visio* and specialized (*MapFlow, ProVision Workbench,* and *SynXpert Process Mapper*™). In the following section 4.7.4 ‘Process mapping software’ more attention will be paid to some of the general-purposes process mapping software such as *iGrafx Process* and *Visio.*

4.7.4 Software

Any general-purposes process mapping software such as iGrafx Process or Visio can be used for drawing a process map. IGrafx Process 2000 is the technological successor of FlowCharter 7 of Micrografx (http://www.micrografx.com/). The key features of the tool are described in the Web site of the iGgrafx as follows:

- Integrated diagramming, simulation and analysis
- Presentation-quality process diagrams
- Easy to use graphical modelling – no coding required
- Powerful 'What If' scenarios for varying simulation variables
- Resource, schedule and cost analysis
- Animated simulation trace capability
- User defined reports displayed in tabular or graphical formats
- Flexible linking of processes to sub processes or external documents

Igrafx can stimulate depicting of all activities and events in a process. It can also represent any configuration of the existing process. Igrafx is described as a "perfect tool" for brainstorming and creative thinking around process improvement. It can model existing processes, then perform 'what-if' analysis graphically in a safe test environment. The tool can create intuitively models, because it is independent in regard to modelling methodology. The simulation can display where process bottlenecks occur and where resources are not used in an appropriate way. iGrafx could be a valuable tool for elicitation, visualisation, analysis and creation of any kind of process variables.

Visio 2000 (http://www.microsoft.com/office/visio/) might also be a powerful tool for eliciting and representing knowledge in process mapping. It can help in building diagrams intuitively and quickly with predrawn drag-and drop task specific SmartShapes symbols. As the product web site says (http://www.microsoft.com/office/visio/standard.htm) they behave "intelligently" - resize without distortion, automatically recalculate direction and length. A custom shape can easily be added to library of stencils. With Visio SmartConectors changes can be made without losing connections. When moving shapes on a page, the links stretch, contract, and change angles in order to stay connected. Visio provides the opportunity for importing already existing data from text files, spreadsheets or databases into diagrams. Another useful characteristic of Visio is the possibility to assign any type of data to the shapes in diagram.

4.8 Information mapping

Information mapping is an approach developed by Horn (1999). The issues that triggered the idea of information mapping were his research on how readers deal with large amount of information in general and specifically how to improve the use of programmed instruction. Section 4.8.1 defines information mapping. Section 4.8.2 presents the theoretical background of the approach. Section 4.8.3 introduces to the information mapping software.

4.8.1 Definition

Information mapping is a research-based approach for analysing, organising and visual presenting of information. Analysis defines purposes, target group needs and information types. Based on the analysis, organisation builds the structure for information. Presentation makes information clear and attractive for audience. The research on the effectiveness of information mapping report on the following: improvements in reading speed; improvements in learning, comprehension, or mastery of topics; reduction in learning time; improved accuracy; reduction in time to retrieve information; improvements in performance for writing tasks; improvements in time-on-task (The Information Mapping Method, 1999).

Information mapping has been successfully used in the domains of information management, training requirement analysis, work flow analysis, training development, proposals, reports and memos, quick reference materials, and training manuals and user guides.

4.8.2 Theoretical framework

Horn (1999) states that the approach is based on learning theory, human factor engineering and cognitive science. No more details are provided. It is only said that information mapping is based on research into how the human mind actually reads, processes, remembers, and retrieves information.

The method has its origin in computer-based learning but recently it has been subject of research in multimedia applications and Web-based training. The *Cisco* (http://www.cisco.com) approach to e-learning with reusable information objects takes into account the advancements in information mapping approach. Information is categorised into seven types: concept, process, principle, procedure, fact, structure, and classification (Wieseler, Katzman, Larsen. & Caton, 1999)

Despate the name, information mapping does not explicitly apply the mapping metaphor. It uses mainly tables as knowledge representation devices. However, information mapping assumes an inherent map structure of information with information items interconnected to each other.

4.8.3 Software

The software employing information mapping is *Formatting Solutions™* (http://www.infomap.com/products/fs.htm). *Formatting Solutions™* integrates the capabilities of user's word processing package or authoring tool in information mapping method. The benefits of the tool are as follows:

- Easy to apply standardised formatting to all documents.
- Standardise formatting created by multiple teams.
- Create easy to read, well-structured documents.

This section introduced information mapping approach. Information mapping is concerned with analysing, structuring and visual presenting of information according to goals, target group and type of information. The approach is based on the research how people perceive, read, interpret and structure information. Information mapping assumed that information items are organised in hidden map structure, but the technique does not apply explicitly mapping metaphor. The ideas behind information mapping might be useful for structuring the information about SMILE method in the learning environment of SMILE Maker.

4.9 Concept system

Concept system is both method and software tool developed by Trochim (2000) (http://www.conceptsystems.com/). Trochim called the approach 'concept mapping' but this is rather loose interpretation of the classical concept mapping approach. In order to distinguish between traditional concept mapping approach and the method Trochim promoted, in this study the term 'concept system' will be used.

4.9.1 Definition

Trochim (2000) interprets concept mapping as a structured process, focused on a topic or construct of interest, involving input from one or more participants, that produces an interpretable pictorial view (concept map) of their ideas and concepts and how these are interrelated. The approach Trochim (2000) introduced is different in a number of important ways from classical approach of concept mapping:

- It is a primarily a group process.
- It uses a very structured facilitative approach – there is a procedure followed by a facilitator to help a group of people to articulate their ideas.

- The core of the approach consists of several state-of-art multivariate statistical methods that analyse the input from all of the individuals and produce an aggregate group product.
- The method requires the use of specialized computer program that handles the data from this type of process and accomplishes the correct analysis and mapping procedures.

There is not a specific theory referred to explicitly to explain the concept system approach. However, it might be assumed that some principles of qualitative and quantitative research paradigms are the rational of the method. In the following section 'Theoretical framework of concept system' some more information in this respect is given.

4.9.2 Theoretical framework

The Concept System approach is an attempt for finding a striking balance between qualitative and quantitative methods. Trochim defined the approach as 'soft science' and 'hard art' (Trochim, 1997). The process has some qualities of both, but does not fall exclusively within either the artistic or scientific domain. Trochim examined the reliability and validity of the methods he used such as brainstorming, sorting, ratings, cluster labelling and final concept map. The criterion is the extent to which the same individual or group gets similar results on multiple occasions, or the degree to which at least two randomly assigned groups independently produce similar results. He discusses several approaches for investigating the validity of the concept system approach. One method is to compare concept maps (or result of any step in the process) with comparable information generated by some other method. A second method for validity is to see whether participants could identify the 'correct' concept map from a set of map. For example, in addition to generating a computed concept map for a project, there might be three more maps, which might have the same statements but randomly placed on map. The question about validity is whether participants could identify the computed map as the one, which most accurately reflects their thinking. Finally it might be possible to examine validity by looking whether concept maps confirm theoretically expected differences. Comparison of concept maps of two groups of participants as how we expect to differ in the their conceptualisations, could help to confirm or deny our expectations.

The Concept system may be particularly useful for theory-driven social research because of its detailed, visual, pattern-based representation of concepts. Trochim described this as pattern matching. In pattern matching there are two patterns – theoretical and observable ones. The theoretical pattern should describe the relationships as they are expected. The observed pattern consists of the relationships that are measured. To the degree that these patterns match and there are no other theories which would account for the observations, it can be concluded that the theory in question is supported. Trochim argues that concept mapping is particularly valuable for pattern matching because it can help researchers to generate their theoretical expectations in detail. He applies both quantitative and qualitative methods in the concept system approach. Some of the steps of the procedure such as preparation, generation, structuring, interpretation and utilization are based mostly on qualitative methods. Other such as representation use statistical methods.

4.9.3 Procedure

The concept system process involves the following six steps:

1. Preparation. There are three tasks to accomplish here:

- Facilitator works with the problem owner to identify the participants.
- Problem owner works with stakeholders to develop the focus of the project.
- Group decides on an appropriate schedule for the mapping.

2. Generation. The stakeholders generate a large scope of statements. Different methods can be used to accomplish this task: brainstorming, brainwriting, nominal group technique, and focus group to mention few of them.
3. Structuring. Two tasks have to be done in this stage:

- Each participant sorts the statements that are similar into piles and give them a name.
- Each participant rates each of the statements on usually a 1-to-5 scale for their relative importance where ‘1’ means that a statement is a relatively unimportant, and ‘5’ means a statement is very important.

4. Representation. In this step the analysis is done – taking the sort and rating input and ‘representing’ it in map format. Two statistical analyses are applied here. Multidimensional scaling takes the sort data across all participants and develops the basic map where each statement is a point on the map and statements that were piled together by more people are closer to each other. Cluster analysis takes the output of multidimensional scaling (the point map) and partitions the map into groups of statements or ideas, into clusters.
5. Interpretation. The facilitator works with stakeholders to help them to develop their own interpretation of the deliverables from previous stages: statement list, cluster list, point map, cluster map, points rating map, and cluster rating map.
6. Utilization. This step involves using maps to address the original focus. The final concept map can be used for planning and evaluation purposes.

Trochim designed a special software tool to support the realization of this procedure. The main components of the software tool are going to be discussed in the next section ‘Concept system software’.

4.9.4 Software

The *Concept System* software is based very much on the procedure that was presented in the previous section. Concept system software consists of the following components:

- User contact info – name, address, username, password, access level, and e-mail of the participants.
- Demographics – job role level, office location, work experience
- Statements – result of brainstorming session
- Sorting – statements clustered in piles
- Rating – statements rated on a 1-5 scale of importance
- Compute maps – similarity matrix, multiple dimensional scaling and principle component analysis.
- Draw map – clusters of statements are placed on the map.

The tool facilitates data collection, information structuring, idea generation, selection of solution and solution implementation stages of the process of solving design problems. The ‘Statement’ component supports *knowledge elicitation*. ‘Sorting’, ‘Rating’, and Computing support *knowledge reflection*. ‘Draw map’ supports *knowledge representation* but also the further analysis of knowledge. There are not special functions supporting *knowledge creation*, but the process may lead to that.

The learning environment of concept system software supports both the approach and software commands. There are five basic components of the learning environment:

- Using concept system help – how the help is structured and some guidelines how to use it
- Concept mapping overview – basic overview of concept mapping and why and how, it can be used.
- Concept mapping process guide – explanation and examples about each step in concept mapping process.
- Concept system software guide – instructions how to use the software.

- Concept system word processor guide – detailed online documentation for qualitative analysis, text abstraction and report generation.

The learning environment is built around the stages of the concept system approach. In each stage a number of supporting process activities and relevant software steps are listed. The learning environment of the tool provides background information about the approach. There are some examples taken from different domains. Guidelines about how to structure a concept system approach are available as well. The download option gives an opportunity to practice partly the approach.

In the following section some mapping software with a broad scope of possible applications is discussed, although it is not related to a particular mapping method.

4.10 Axon Idea Processor

Axon Idea Processor is integrative mapping software combining support for different mapping approaches and a specific graphical editor (http://web.singnet.com.sg/~axon2000/index.htm). There is not a particular mapping method that Axon Idea Processor is based upon. It is defined as a sketchpad for visualizing and organizing ideas. Figure 10 shows a screenshot from *Axon Idea Processor*.

Ideas and diagrams are the basic abstractions of the Axon. Ideas are shown as graphical objects and their relationships are shown as links. Users get the big picture and details can be hidden from view. The Web site (http://web.singnet.com.sg/~axon2000/index.htm) of *Axon* says that the software provides an environment for supporting thinking as the tool explores visual attributes such as shape, colour, size, depth, position, links, etc. A user can use similar shapes or colour to associate ideas, and use a larger size to emphasize an important idea. Visual cues facilitate recall, association, and discovery. Diagrams help to organize cognitive activities and select approaches to problem solving.

The benefits of the tool are expressed in the following way:

- Work with ideas and concepts rather than words.
- See the Big Picture and not get lost in details.
- Analyse and solve complex problems.
- Improve user’s memory and recall.
- Stimulate creativity and discovery.
- Facilitate knowledge capture and transfer.

- Effectively amplify mental potential.
- Focus attention and minimize distractions.
- Reduce mental fatigue and writers' blocks.
- See relationship from different perspectives.

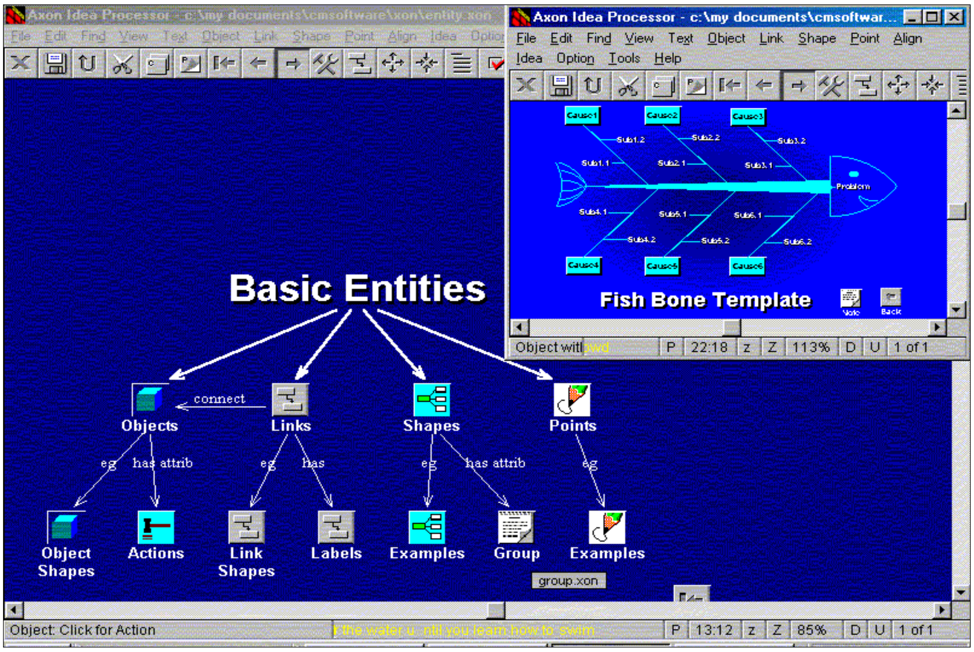


Figure 10. A screenshot of Axon Idea Processor

Axon based its application on recent cognitive psychology research evidencing that thinking processes occur in no particular sequence. This suggests the concept of 'mode-lessness'. A mode-less system enables a user to perform any task at any time without having to switch modes. In contrast, a traditional modal system requires entering different modes to perform different functions. Using *Axon*, one can work top-down, bottom-up, and not restricted by fixed procedures. Writing, drawing, organizing, and computing, can be done concurrently without having to switch tools.

Axon makes available some tools that could facilitate *knowledge elicitation*. They are as follows:

- Use templates. The best way of knowledge elicitation that Axon proposes is to select a template and then to elaborate on it, or modified it. Some of the templates that the tool offers are concept maps, mind maps, causal diagram, fish-bone diagram, 'how-how' diagram, 'why-why- diagram, logic diagram, SWOT analysis, synectics, 'six thinking hats', and lotus blossom.
- *Axon* applies three entities for making diagrams – objects, links and shapes.

 – An object corresponds to an idea, a concept, an abstraction, a node, a keyword, a cell, and etc. An object is identified by an ID and shown in different shapes such as box, bar, ellipse, diamond, and etc. An action is associated with each object. Objects can be connected by links.
 – Links. A link is an arrow joining two objects. Links show cause-effect or other relationships between objects. They are used to sequence objects. Links can be used for navigation, computing functions such as sum, logic functions, and PERT, and to form clusters. Links can have various link shapes. There is a possibility for cross-links, which connect two objects not in the same level.

Axon offers some good opportunity for *knowledge reflection*. They are listed as follows:

- Analyser. The following types of analysis can be performed by this function: ID causes, ID effects, ID sequenced, ID sorted, abstracts, checklist frequency, checklist word, clauses, index, links, proper nouns, sentences, spelling, statistics, syllables, and word length. A draft report can be generated from the Analyser.
- Cluster. A cluster shape could be assigned to a parent object. Child objects in a cluster are automatically sequenced. There are different cluster shapes: elliptical, circular, star, bottom tree, right tree, left tree, top tree, and arbitrary.
- Computing. Axon allows computing like a spreadsheet.
- Project management. Axon has a special algorithm to solve PERT problems.

The features of *Axon* for *knowledge representation* are as follows:

- Background patterns, textures and clipart
- Integrated drawing tool and icon library.
- 3-D, 500-level workspace
- Different spatial configurations

Axon posses some well elaborated options for *knowledge creation*:

- Checklist. Checklists are collection of items. Each checklist could be assigned up to 16 topics. A checklist item could lead to another checklist. The combination of items and format of items (concepts, facts, questions, ‘how to’, diverge, or converge) is possible.
- Questions. Axon generates a list of questions related to the word that is put in Idea box. The software also provides a database of generic questions for idea processing.

- Random word. The Random Words feature is an extension of the Checklist System. Random Words are generated from one or two Checklists. When user generates random words from one checklist, he or she can try to relate current problem and the generated idea. When user generates random words from two checklists, he or she can try to find a relation between two unrelated ideas. This could stimulate generation of new ideas.

4.11 TheBrain

TheBrain is mapping software developed by *The Brain Technologies Corp*. (http://www.thebrain.com/). *TheBrain* is an information management tool that helps in organizing and navigating through all information available in a computer in a very personal manner. A user can create structures of information that reflect the way he or she thinks about information. Figure 11 presents an example of *TheBrain*.

TheBrain uses a new metaphor – human mind and structures of knowledge. It transforms computer into a digital version of mind. The tool applies a new data format called "thoughts". They could be ‘forgiven’ and ‘recalled’. ‘Thoughts’ can be any type of information, including documents, spreadsheets, images, and web pages. The tool shows how these pieces of information are related providing visual dynamic context. *TheBrain* expresses the natural multi-layered relationships that exist in the real world. The dynamic environment of the tool provides opportunities for changing the perspective of looking at information. Providing flexible associations between information items transforms information into knowledge. Thus, *TheBrain* can be defined as a knowledge management tool.

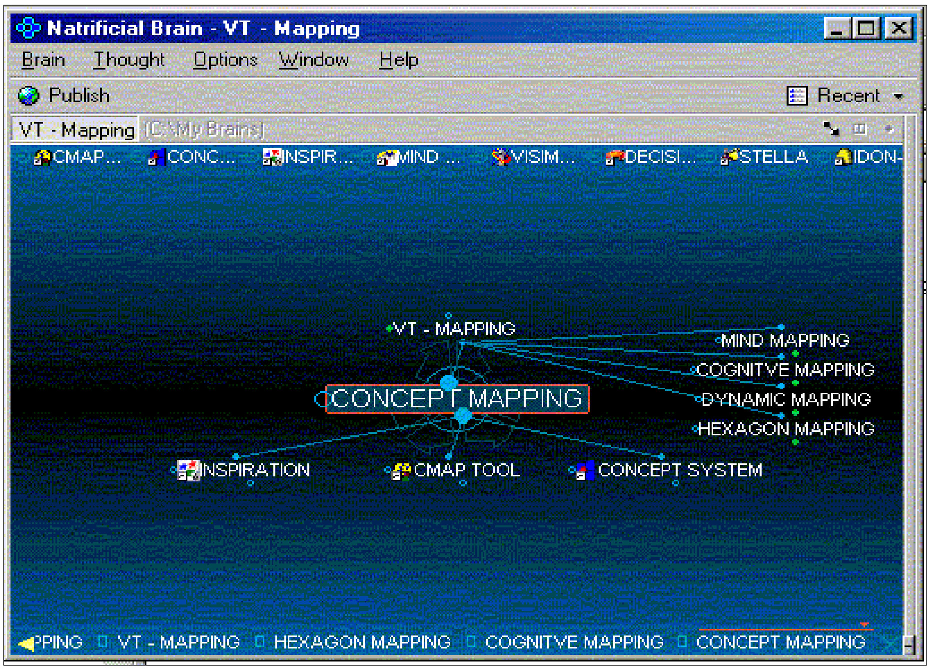


Figure 11. 'TheBrain' on concept mapping

The interface of *TheBrain* lets users to browse visually through its unique, animated display intuitively by pointing and clicking. Adding new information and integrating existing information is a simple drag and drop. Because of its unique functionality and interface, *TheBrain* brings a sense of control over a large and complex amount of information. It could make the software a powerful and attractive navigation tool. *TheBrain* can be used also as a site map of web-based environment.

4.12 Site maps

In this section some mapping software designed to serve as site maps is presented. These are ThinkMap (http://www.thinkmap.com/) and Dynamic Diagram - MAPA2 (http://www.dynamicdiagrams.com/Home.htm) Web-based site maps are defined as a visual representation of a web site structure (Pilgrim & Leung, 1999). They improve spatial context and reduce disorientation, provide a sense of extent of a particular web site without giving details, serve as a visual surrogate for using short term memory, and support the task of browsing by providing orientation.

The *ThinkMap* web site (http://www.thinkmap.com/) describes the software as a tool that animates and displays complex sets of interrelated information, and create interfaces that transform data into insights and knowledge. In a project with the Smithsonian Institute, Think Map technology has been used as museum collection browser. A user can navigate effectively through objects of an exposition. The view of objects can be customised by a user and presented in different context. Figure 12 gives an example of ThinkMap project with Smithsonian Institute.

Figure 12. ThinkMap project with Smithsonian Institute

Another example of applying ThinkMap is the Bacardi site (http://www.bacardi.com/). Bacardi used Thinkmap to create a contextual and interactive interface that shows the relationships between the various aspects of the Bacardi brand. Navigating through the Bacardi site provide various information about Bacardi company.

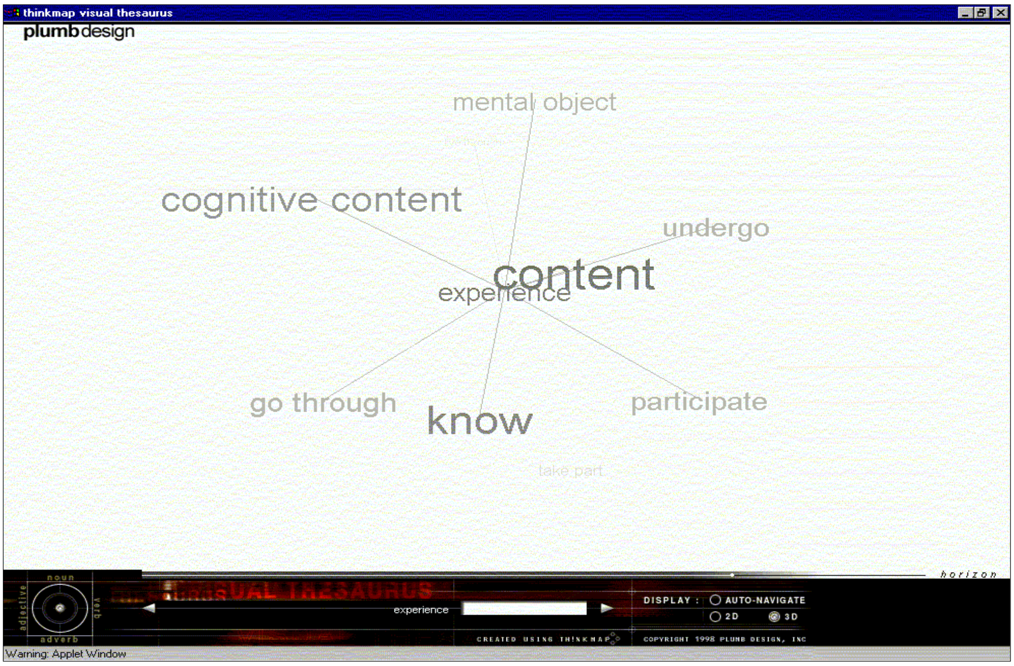


Figure 13. Plumb Design Visual Thesaurus

The *Plumb Design Visual Thesaurus* (http://www.plumbdesign.com/) was developed as a demonstration of Thinkmap.

The application is linked to the WordNet database created by the Cognitive Science Laboratory at Princeton University. Figure 13 shows the sense of relationships of words in the English language. Users can change the emphasis of the search, control the behaviour of the display, determine the movement of words by adjusting font-size, scale, and speed of rotation, search for any word or phrase in a simple text-entry box, view the history of visited words and revisit previously chosen words in a separate display.

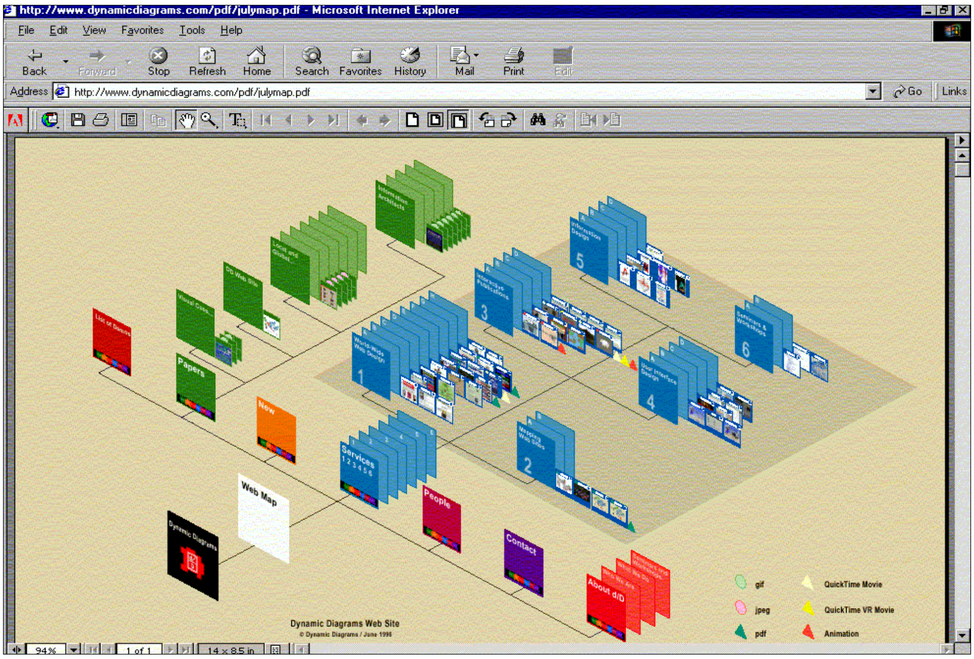


Figure 14. A screenshot of MAPA Software

MAPA is a product of Dynamic Diagrams (http://www.dynamicdiagrams.com/Home.htm). It is a technology supporting the development of Web site overviews. Figure 14 presents an example of this mapping software.

4.13 Mapping approaches – summary

This section summarizes the main points of the analysis of different mapping approaches. Each type of mapping was considered within the framework of four headlines: definitions, theoretical framework, procedure and software. The analysis focused on the specifics of these mapping approaches. This section consolidates these characteristics in order to derive what is common between the mapping approaches. The main question that the section addresses is ‘What makes mental maps powerful techniques for solving educational and training design problems?’

There are two concepts that might contribute to the answer of this question. These are isomorphism and distributed cognition. Isomorphism reflects presumed one-to-one correspondence between information captured on the map and a reality. When map attempts to represent some implicit cognitive reality, each symbol has one-to-one relationship with an idea or a construct and the arrangement of the symbols should show how knowledge items or ideas are interconnected.

4.13.1 Map metaphor

While being based on different theoretical paradigms and referred to various theories, all mapping approaches (exception only information mapping) have map as an explicit metaphor. Information items are interconnected in a nonlinear spatial layout. The theories of radiant thinking (mind map); mental models (dynamic mapping; hexagon mapping); patterning system (flowscaping); information processing (concept mapping, mind mapping, dynamic mapping) and assimilation theory (concept mapping) argued that the human mind stores information in a map format where nodes represent different types of information items which are interconnected. The theories behind different mapping approaches are based on some contemporary physiological and psychological research which proved that a mental map is an adequate, accurate, flexible and practical model of expressing the ways our minds receive, store, organize and change information. The body of knowledge is built by a set of information items connected to each other in a spatial layout which varies in its format– hierarchies, networks or matrix. Map-making realizes a close correspondence between psychological constructs and their external mode of representations. Mental maps are analogous to the mental organization of individual cognitive structures. This representation of mental patterns is perhaps not perfect but expresses the systematic relationship that can be used as a basis for derivation of inferences about state of that pattern. The cognitive structures that a map should reflect are given different names – semantic memory (Quillian, 1988); mental models (Hayes-Roth & Hayes-Roth, 1988; Norman, 1993; Schank, & Abelson, 1988, Venix, 1997), patterns (De Bono, 1994), knowledge structures (Jonassen, Beissner & Yacci, 1993; Novak, 1998), schemata (Rumelhart, Smolensky, McClelland & Hinton, 1988); or scripts (Schank &Abelson, 1988). Whatever name is attached, they reflect the same reality and have very similar content and functions. The most used terms are mental models and patterns. For convenience 'mental pattern' or just 'pattern' will be used further in this analysis. We used pattern to assimilate incoming information into existing structures. If a pattern is not adequate enough we modify or accommodate it to fit to available information. In well-structured problem-solving situations we try to recognize and retrieve the appropriate pattern and to apply it to the problem. In ill-structured situations, which are the case in most of educational and training design situations, combinations between components of different patterns or different levels of modification of existing patterns should be constructed and tested. Mapping supports pattern-using and pattern-making because it mimics the internal content and the structure of patterns. This general characteristic makes mental maps powerful tools for knowledge *eliciting, representing, reflecting and creating.*

4.13.2 Knowledge elicitation

Because of its similarity with pattern organization, a mental map should be expected to have a potential for a quick recognition and retrieval of information. The visual character of the map could provide a means for structuring cognitive activities during retrieval. Concepts and the labels have the potential to act as cues that could guide a search through cognitive patterns. The use of a map then would be expected to improve the accessing of relevant knowledge because of its capacity to influence both organizational and retrieval events. In addition the visual presentation of patterns makes pattern recognition easy. Recognition being one of the most substantial underlying mechanisms of perception is a faster cognitive process that retrieval (Eysenk & Keane, 1995). At the same time it makes the retrieval process more effective and efficient. Mental maps involving perception can enhance thinking processes.

4.13.3 Knowledge representation

A mental map shows a whole picture of a problem solving space and the relationships between its components and how they are represented in the mental patterns of people. The complexity of the problem situation can be grasped at once. While a mental map is concise, compact, and parsimonious, it is at the same time very rich in information. Maps are special chunks of information because of their strong integrative potential. A map is a device capable of reproducing complex problem situations in an easy and an intuitive way because of opportunities to expresses the variety of problem solving representations (facts, statistics, opinion, and feelings) and the variety of relationships between them (descriptive, structural, causal, metaphorical) using a simple format (nodes, links and labels on the links). Mapping integrates two kinds of coding - verbal and visual. The technique capitalizes on the advantages of graphical representations without losing the flexibility and the power of the natural language system.

4.13.4 Knowledge reflection

Mapping allows reflection on and analysis of mental patterns about a particular problem solving situation and investigation of the relationships and configurations between components of this pattern. Apart from reflecting-on the results of thinking during problem solving a problem solver could as well as reflect-in the process of the analysis of the problem situation, generation of alternative solutions, selection of the most relevant solution and implementation of solution into practice. Reflection should not be considered as a single episode. It accompanies the entire process of problem solving. Making the internal problem solving processing explicit via a mental map could contribute substantially to knowledge reflection. Mental maps supports reflection-in-action during problem solving (Schön, 1996) involving perception on the externalised cognitive structures and processes.

4.13.5 Knowledge creation

Map-designing and map-interpreting involve complex cognitive transformation with both intellectual and visual components. Mapping and especially mapping software allow problem solving representations to be manipulated in their externalised states. The position of items and spatial configuration could be changed in order to see different perspectives, new possibilities can be explored, and as a result new ideas might be generated. Thus, when working upon a map we are building upon our cognitive structures. This is a mutual process: while improving the external model of a pattern we improve pattern effectively. This unique characteristic of mapping software challenges the assumption that it is not possible to build a new pattern through reconstructing of the old one (De Bono, 1990). It is argued that with the help of lateral thinking techniques is possible only to create a completely new pattern along with old ones. It is impossible to modify old pattern in such extent that it can result in producing a perfectly new one.

Mapping supports mental imagery. It can be seen as a flexible mode of visual representation, which allows a rapid anticipation of transformations in a problem situation. Visual imagery facilitates problem solving because of the possibility to tap visual perception directly. One of the major functions of imagery is to mentally anticipate on potential issues of problem solving.

An additional concept that may contribute to explaining what make mapping a powerful tool for solving educational and training design problems is *distributed cognition* (Perkins, 1993; Rogers, 1997; Salomon, 1993). Distributed cognition is considered as a new theoretical paradigm. The classical paradigm views cognition as a localized phenomenon. The distributed cognition paradigm emphases the distributed nature of cognitive phenomena across artefacts and individuals (Rogers, 1997). Perkins (1993) makes a distinction between the traditional concept of *person solo* and *person plus*. 'Person solo' is an individual without resources in his surround while 'person plus' should be considered together with his or her surround.

4.13.6 Maps as artefacts

"Surround" is defined as the immediate physical or social resources and artefacts outside of a person participate in cognition not just as a source of input and a receiver of output, but also as means of thought. The results of thinking are located not just in the mind of an individual but also in the arrangement of the surround. However the point is not the localization of cognition but the extent to which external representations and artefacts support perception, memory and thinking. In this sense mental maps as artefacts afford a physical distribution of cognition. Doing so they could support knowledge elicitation, knowledge reflection, knowledge representation and knowledge creation because of externalisation of internal problem solving structures and processes. Mapping gives an opportunity to see internal problem solving representations, to reflect on and eventually to change them.

4.13.7 Maps and cognitive overload

Mapping supports the natural drive of people to reduce cognitive overload by making explicit internal problem solving processes. Mapping might reduce cognitive overload not by reducing but by managing the complexity of a situation. Working memory where most of the processes of problem solving take place has limited potential. In ill-structured situation many factors play a role, information is vague and incomplete, there are not criteria for recognizing the appropriate pattern and uncertainty occurs over constructing a new pattern to address the problem. Many of the people experience difficulties while dealing with their internal thinking processes. It is hard to look upward and to communicate with yourself about your thinking processes during ill-structured problem solving. In addition to that there are always two parallel processes - thinking about the problem itself and thinking about the thinking. This makes the issue of problem solving much more sophisticated (Merriënboer, 1997). The mental models of our own cognitive processes are rather difficult to deal with and this raises the need for a tool that can externalise these mental models. Maps are quite relevant means for that. They are an external extension of working memory, enlarging its natural capacity. A map as a short-term memory surrogate can function as an external memory aid. It enables a problem solver to grasp complex interactions among concepts that could otherwise potentially exceed his or her cognitive capacity. The externalisation of mental problem solving patterns involves effective perception which amplifies thinking and memory. We cannot directly observe internal thinking events, only external indicators of thinking such as mental map.

4.13.8 Map as metacognitive tool

Mapping can stimulate self-appraisal and self-reflection, giving a sense of distance and ownership. We need to distinguish ourselves from our internal world in order to understand it. The externalisation of the cognitive processes enhances the internal locus of control of a problem solver on them. Mapping can stimulate self-management. It is a cognitive instrument for planning and guiding the activities through the various problem-solving stages: problem formulation, information collection, idea generation, idea selection, and idea implementation.

The Table 1 presents the main features of the discussed in this chapter mapping software in regard to the support of problem solving and the learning environment they provide.

Table 1. Comparative table of the mapping software

Mapping Software	**Mapping Method**	**Application in**		**Problem solving support**				**Learning Environment**					
												Support	
		Educational settings	Business settings	Eliciting	Representing	Reflecting	Creating	Explanations	Procedures	Examples	Practice	PS method	Graph. editor
Inspiration®	Concept mapping	✔	✔	✔	✔	✔	✔			✔			✔
Concept mapping toolkit	Concept mapping	✔		✔	✔	✔	✔		✔	✔	✔		✔
STELLA®	Causal mapping		✔	✔	✔		✔	✔		✔	✔	✔	✔
Mind Manager	Mind Mapping	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔		✔
Decision Explorer	Cognitive mapping		✔	✔	✔	✔		✔	✔	✔	✔	✔	✔
Idons-for-Thinking	Hexagon mapping		✔	✔	✔	✔	✔	✔	✔	✔			✔
Concept system	Trochim's concept mapping		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Axon Idea Processor	Integrative approach		✔	✔	✔	✔	✔		✔	✔			✔
Process mapping Software: • iGrafx • Visio 2000	General-purposes	✔	✔		✔	✔							✔
Formatting Solutions™	Information mapping	✔	✔	Does not apply the mapping metaphor									

Chapter 5. Design and development of the SMILE Maker Tool

This chapter reports on the process of designing, developing and formative evaluation of the SMILE Maker. Basically the chapter is related to the research question 'What are the design solutions implemented in the SMILE Maker Tool?' SMILE Maker applies the ideas discussed in the previous chapters concerning problem solving, learning and mental mapping. The process of transforming the ideas into design solutions and developing of workable models is the objective of the current chapter.

At the beginning the chapter refers to the issues of applying mental mapping for solving educational and training problems (Section 5.1). Further, the chapter reports on the design framework, and phases of designing, developing and evaluating the SMILE Maker (Section 5.2).

5.1 Issues that SMILE Maker Tool addresses

Section 1.3.4 discussed some of the problems of using concept mapping for solving design problems. Here these problems are presented in a dichotomous format as observed discrepancies between 'what is' and 'what should' be conditions.

- **Concept mapping as learning and teaching technique versus a concept mapping as design technique.**

  Concept mapping is used mostly as learning and teaching technique. As a learning tool it frequently is used to supports the relatively low levels of learning taxonomy – remembering and comprehending. In the design process concept mapping facilitates higher order skills and complex learning such as problem solving.

- **Concept mapping as a knowledge representation technique versus concept mapping as a knowledge elicitation, knowledge reflection and knowledge creation technique.**

  Concept mapping is generally considered as a technique for representing particular subject matter knowledge. However, it has the potential to also support knowledge elicitation, knowledge reflection and knowledge creation. These functions are especially beneficial for the design process. There are at least three issues in respect to concept mapping as a knowledge elicitation technique. Firstly, external information about design problems is very complex, messy, vague and incomplete. Secondly, there are difficulties related to the articulation of structural knowledge that is stored in the long-term memory of individual. Thirdly, short-term memory has a limited capacity to deal with the increasing number and contradictory nature of information items. Concept mapping as a *knowledge reflection* technique should help in analysing the model of the design situation. New groups of items and a new structure of the model can be formed. Elicitation, representation and reflection stimulate the *creation* of new knowledge. Concept mapping has the capacity to change the perception of the configuration of knowledge patterns and thus the creation of new ideas.

- **Mapping software as a drawing tool versus mapping software as a cognitive tool.**

  Most of the mapping software packages emphasise the characteristics that support drawing - making nodes, drawing links, posting labels, changing shapes and colours, and the like. No much support is attributed to the mapping methods themselves (purposes, theoretical framework and procedures) and how they could contribute to knowledge elicitation, reflection and creation. Mapping software packages, as drawing tools, do not directly lead to designing effective and feasible solutions. They do not afford implicitly the functions of eliciting, reflecting and creating knowledge. They are not embedded in mapping software which is considered only as a drawing tool only. The design power of mapping approaches has to be shown explicitly.

- **Concept mapping versus other mapping approaches.**

  Apart from concept mapping there are other mapping approaches such as cognitive mapping, mind mapping, causal mapping, hexagon mapping, and process mapping. They each have their own purposes, theoretical framework and software but share some common characteristics of mental mapping. These mapping approaches could bring valuable insights for developing a problem solving method that supports elicitation, reflection, representation and creation of knowledge.

- **Framework support versus operational support.**

  Existing educational design approaches provide a valuable framework for design activities but do not go further on a more detailed level to give operational support for analysing the design situation, collecting needed information, generating alternative solutions, selecting solutions and implementing solutions. They do not propose instrumental knowledge, techniques, tools, guidelines, procedures, examples and demonstration for these design activities.

- **Individual problem solving versus group problem solving.**

  Any methodology for solving design problems should take into account either the effects of individual problem solving syndromes or group dynamic characteristics. Negative problem solving syndromes might influence the problem solving process. Some preventive actions should be undertaken against the effects these syndromes, mental blocks and barriers might create. Apart from that the learning environment of a tool promoting a method for solving design problems should support developing versatile individual problem solving styles. Versatility also is important for the group's composition and cohesion.

Table 2 summarises the issues of using concept mapping in the educational design process. It shows how concept mapping and educational design have been traditionally considered and how they should be considered.

Table 2. Concept mapping issues

'What is'	**'What should be'**
Mapping	
Teaching technique Learning technique	Design technique
Knowledge representation	Knowledge representation Knowledge elicitation Knowledge reflection Knowledge creation
Concept mapping	Concept mapping Mind mapping Cognitive mapping Causal mapping Hexagon mapping
Educational design	
Framework	Operational support
	Individual problem solving characteristics Group dimensions

This analysis of issues applied to concept mapping for solving design problems in education leads to some ideas that should be taken into consideration in developing a tool to solving design problems. They are as follows:

- Concept mapping should support people in the process of solving design problems providing tools and techniques for collecting information and analysing the current situation, generating alternative solutions, selecting the most appropriate one(s) and implementing the solution(s) into practice.

- The educational and training design process should explore concept mapping as a knowledge elicitation, knowledge reflection, knowledge representation, and knowledge creation technique.
- The learning environment in which mapping software is used should provide support for studying how to apply mapping approaches for solving design problems.
- In addition to concept mapping attention should be paid to other mapping approaches such as cognitive mapping, mind mapping, causal mapping, and hexagon mapping.
- An educational design framework provides the design activities with logic and perspectives but it need to be concretised in the terms of more explicit procedures, examples, techniques and tools.
- Educational design methodology has to take into account the possible effects of both individual and group conditions on solving design problems.

The dichotomous format of presenting the issues of applying concept mapping in solving educational and training problems does not imply mutual exclusiveness under the Scheme ‘neither – or’. A positive idea might be to establish a balance between the two opposite extremes in each case. Thus, based on the characteristics of the issues presented so far, this dissertation project established as its goal designing, developing and evaluating a tool for solving design problems. It is aimed at building an individualised learning environment for promoting a method for solving design problems applying the advantages of mental mapping approaches and implementing some creative problem solving principles and techniques. The tool should provides just in time, just enough, and at the point of need individualised facilitation of solving design problems. Initially the tool was given the name ‘Brain Map’. Later on the name changed to SMILE Maker which reflects more adequately the design objectives of the current project. SMIILE stands for Solution, Mapping, Interactive Learning Environment. For convenience throughout the text that follows, the term SMILE Maker is going to be used. Next section 5.2 ‘SMILE Maker – design methodology outlines the rational for the activities of designing and developing of the tool.

5.2 The SMILE Maker design methodology

This section reports on the design methodology that was adopted for development of the SMILE Maker Tool. Section 1.2.2 discussed some tendencies in the development of design models in education and training. It was stated that the most of the contemporary educational and training design models tried to combine rational and relational approaches. However, a few of them relate this conceptual shift to a design framework operationalising both approaches in a set of activities in order to provide perspectives to designers. The SMILE Maker Tool needed a design methodology based on a strong scientific grounds, presenting a framework for the main activities and procedures and giving some guidelines while being flexible enough to provide room for concrete context-sensitive design applications. Such a design methodology is the 3-Space Design Strategy (Moonen, 1999, 2000, 2001). The set of criteria on which the choice of this strategy was made is presented as follows:

- The 3-Space design strategy converges theoretical perspectives and practical achievements in the domains of computer science, instructional design, multimedia and WWW.
- The 3-Space design strategy takes into account the development of educational and training design methodologies, software design approaches and project management perspectives.
- The 3-space design strategy combines two widespread design approaches: bounded-rationality (Simon, 1972) and reflection-in action (Schön, 1996).
- The 3-Space design strategy provides a space for integrating the advantages of the rational, deliberate, prototyping and artistic educational design approaches.
- The 3-Space design strategy builds a framework and proposes some general guidelines for structuring design activities.

The 3-Space strategy consists of three spaces: the consensus space (between rationality and social constructivism); task space (from specifications to partial products; and implementation space. Moonen (1999, 2000, 2001) prefers to use the term 'spaces' instead of the more traditional 'phases' to avoid the suggestion of linearity.

- The goal of the consensus space is to "move from an unstructured situation and very global ideas and specifications toward a structured design problem and appropriate versions of the functional specifications" (Moonen, 2000, p.20). The term 'consensus' traditionally connotes reaching convergence on the design ideas of group of stakeholders. This meaning of 'consensus' is valid in the case of the 3-Space design strategy as well. However this type of design space emphases especially on the convergence of rational and relational approaches to designing educational products and this is the main point of distinction from other design spaces. (Moonen, personal communication, 2001). The group factor plays important role in the design process but not necessary at the beginning. A mock up developed by an individual designer could become a subject of consolidation of the opinions and concerns of the people involved in the design process. The deliverable of the consensus space is a set of specifications.

- The objective of the task space is to elaborate on the functional specifications and construct one or a few mock-ups or prototypes. After formative evaluation a final prototype should be developed.
- In the implementation space end users work with the final prototyping product trying to adapt it to their specific needs.

The remainder of this chapter presents an interpretation of the 3-Space Design Strategy in the context of design and development of the SMILE Maker Tool. Table 3 shows the time-line of the designing, developing and evaluating the SMILE Problem Solving Method and the SMILE Maker Tool.

Table 3. The SMILE Maker timetable

	Activities	'98					'99				'00				'01
			Mar	June	Sept	Dec	Mar	June	Sept	Dec	Mar	June	Sept	Dec	Jan
1	Design the SMILE PS Method	■	■	■											
2	Qualitative evaluation of the SMILE PS Method			■											
3	Quantitative evaluation of the SMILE PS Method				■	■									
4	Design the SMILE Maker Tool - specification			■	■										
5	Development the SMILE Maker Tool														
	• Mock-up				■	■									
	• Mock-up evaluation					■									
	• New specification – design model						■								
	• Prototype							■	■	■					
	• Supportive Web site											■			
6	SMILE Maker Tool evaluation:														
	• Qualitative evaluation of the SMILE Maker Tool													■	■
	• Quantitative evaluation of the SMILE Maker Tool													■	■

5.2.1 SMILE Maker consensus space

The consensus space of the SMILE Maker Tool involved some activities concerning the conceptual design of the tool. It included collection of information and analysis of the design situation (Section 5.2.1.1), generation of ideas (Section 5.2.1.2), first functional specification of the tool (Section 5.2.1.3), and the SMILE Maker design model or second specification.

5.2.1.1 Information collection

The purpose of this consensus sub-space is to analyse the theory and practice of using mental mapping in the educational and training design process. It should assemble and organise all available information in this respect. A visual brainstorming through concept mapping was applied in order to collect the relevant information for designing the SMILE Maker tool. Information collection reflects most of the achievements in the chapters 2, 3 and 4. It consists of three major parts: problem solving, mental mapping and learning. Figure 15 represents the results of information collection in a mind map format. 'Problem solving' and 'mapping' reflect developing the SMILE problem solving method of the SMILE Maker tool while 'learning' is related to development of the learning environment of the SMILE Maker tool.

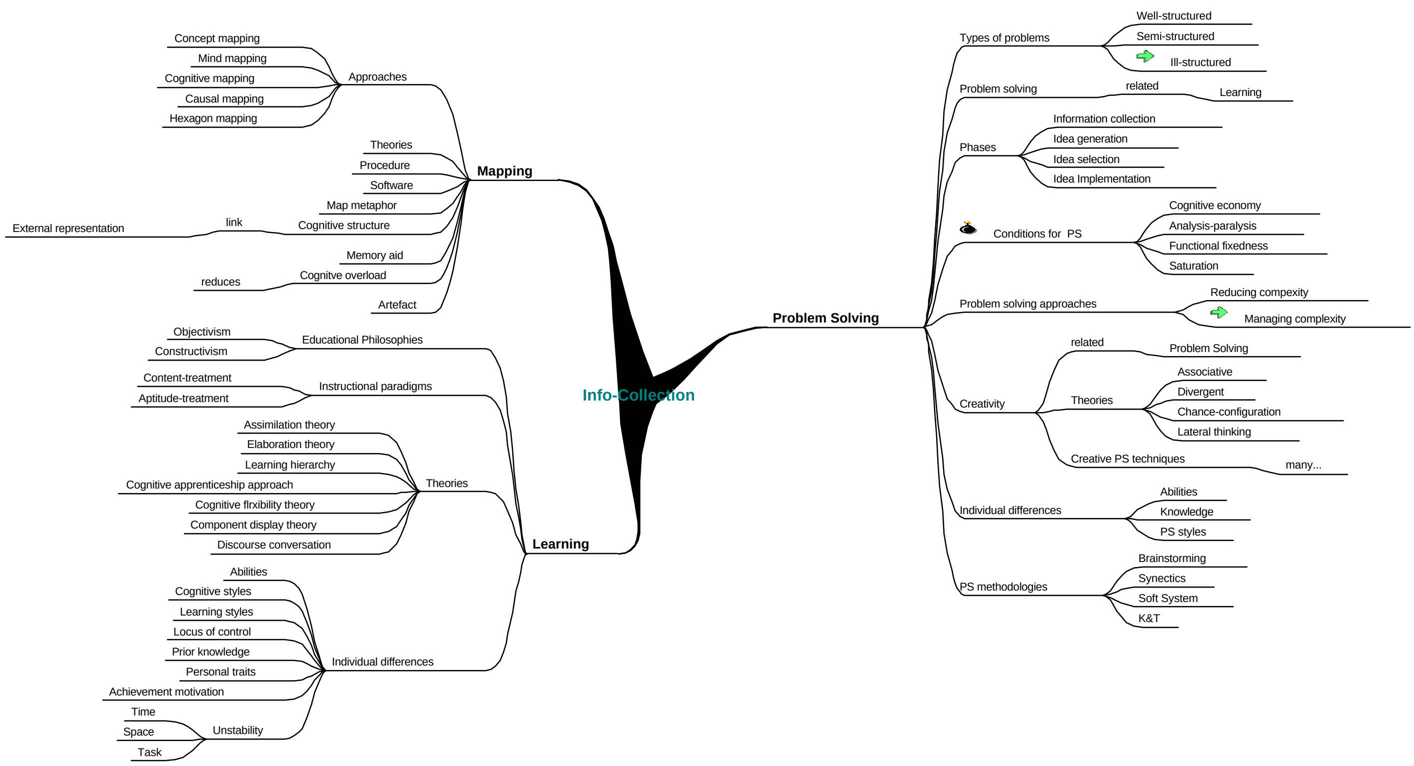


Figure 15. The SMILE Maker design - Information collection

5.2.1.1.1 Problem solving

- Different types of problems have been identified – well structured, semi-structured, and ill structured; presented, foreseen, constructed, and deceptive.
- The research conducted within the conceptual framework of Gestalt psychology, behaviourism and cognitivism showed that problem solving and learning are categories closely related to each other.

- Problem solving is an iterative process consisting of stages the most refereed to being information collection, analysis of problem situation, problem definition, idea generation, idea selection, and idea implementation.
- Some negative conditions for problem solving have been reported: cognitive economy, analysis-paralysis, functional fixedness, stereotyping, tunnel vision, saturation, fear of making mistakes, inability to reflect on ideas, a preference for judgment, reluctance to implement ideas, taboos, and lack of correct information.
- Two general problem solving approaches have been identified: reducing complexity and managing complexity.
- Problem solving and creativity are related to each other.
- Different theories of creativity exist: divergent, associative, chance-configuration, and lateral thinking.
- Many creative problem solving techniques have been invented and applied in practice.
- Individual differences in abilities, level of prior knowledge and problem solving styles could affect problem solving.
- Several integrated problem solving methodologies have been used for a certain period of time. Some of them are brainstorming, soft system methodology, rational approach, and synectics.

5.2.1.1.2 Mental mapping

- There are different mapping approaches – concept mapping, cognitive mapping, causal mapping, mind mapping, flowscape, and hexagon mapping.
- Mapping approaches apply a map metaphor in representing problem situations.
- Mental mapping approaches realise a close correspondence between cognitive structures and external mode of representation.
- Mental map is an external memory aid.
- Mental mapping reduces the cognitive overload during problem solving.
- Mental mapping stimulates self-management in problem situations.
- Mental maps are artefacts of distributed cognition.
- Mapping approaches are based on different theories, apply different procedures and are implemented in different software.

5.2.1.1.3 Learning

- There are two main educational philosophies: objectivism and constructivism.
- There are two general instructional paradigms: content-by-treatment interaction and aptitude-by-treatment interaction.
- Several instructional design theories were accounted: assimilation theory, learning hierarchy theory, elaboration theory, component display theory, activity theory, cognitive apprenticeship, cognitive flexibility theory, and discourse conversation.
- Taxonomy of individual differences may include the following constructs: abilities, cognitive styles, learning styles, locus of control, prior knowledge, personal traits, and achievement motivation.
- Individual constructs are unstable over time, space and tasks.

5.2.1.2 Idea generation

This sub-space reflects basically the ideas coming from the analysis of problem solving, learning and mapping paradigms. Problem solving and mapping contribute to the design and development of the SMILE method while learning paradigm contributes to design and development of the learning environment of the SMILE Maker. Figure 16 shows a mind map after idea generation.

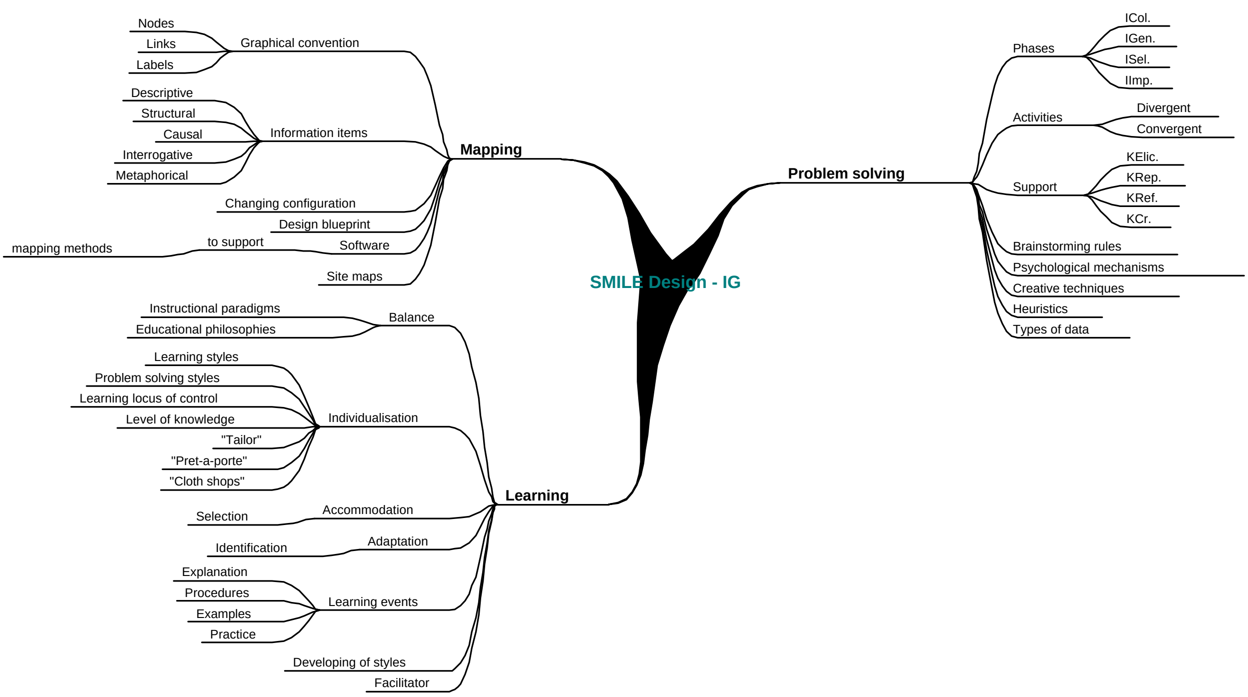


Figure 16. The SMILE Maker design - Idea generation

5.2.1.2.1 Problem solving

- Solving educational and training problems should be considered in systematic terms as a process consisting of several stages, which have particular objectives. The most common stages are information collection, problem definition, idea generation, idea selection and idea implementation. It is iterative process with possible loops between stages.
- Each stage of problem solving should include both divergent and convergent activities. Divergent activities are organised to broaden the views on problems. Convergent activities are organised to reduce the amount of ideas to a reasonable size based on a set of criteria. As a rule, a stage should begin with some divergent activities, before switching to some convergent activities.
- Promoting a set of creative problem solving techniques to support activities in each of the stages of problem solving. The support should be differential, as these techniques preferably should facilitate knowledge elicitation, knowledge reflection, knowledge representation and knowledge creation in the phases of information collection, idea generation, idea selection and idea implementation.
- The rules of brainstorming, the problem solving guidelines, principles and operational mechanisms, the concrete procedures of creative problem solving techniques and the comprehensiveness of problem solving methodologies should be taken into consideration as well. The method might benefit from some creative problem solving principles such as knowing how to see; thinking fluently; looking in other worlds; connecting unconnected; making novel combination; and making your thought visible. Synectics adds some more useful operational guidelines such as ‘making strange familiar’ and ‘making familiar strange’ and it demonstrates the power of metaphors and analogies. Soft system methodology emphasizes on the pictorial representation of problem situation and reflection on it. The brainstorming rules of quantity breads quality, defer judgment, freewheel and hitchhike also might be put in operation. The SMILE method could refer to some of the creative problem solving techniques such as attribute listing, morphological analysis, analogies, metaphors, free association, brainwriting, listing, lateral thinking techniques and tools, weighting systems, and potential problem analysis.
- New creative techniques could be developed on the basis of some mapping characteristics and creative problem solving principles, mechanisms and techniques.
- The creative problem solving techniques within the framework of a problem solving methodology might be considered as special heuristics.

- Different types of data might be collected: objective data (facts and statistics about who, what, where, when, why, and how of the situation), subjective data (opinions, attitudes, feelings and beliefs) and details about any constraints that exist (legal, financial, time).
- Mental maps as artefacts could amplify the effect of creative problem solving techniques to ‘manage complexity’ of problem solving.

5.2.1.2.2 Mental mapping

- The SMILE method might apply the graphical convention of concept mapping: nodes, links between them and labels on the links. The nodes may represent any sort of information items: facts, opinions, metaphors, feelings, etc. The labels on the links might express descriptive, structural, causal, interrogative and metaphorical relationships. The spatial configuration might be hierarchy, network or matrix.
- Mental maps provide a whole picture of a problem solving situation giving opportunity for reflecting-on, and reflecting-in its structure.
- The components of mental maps could be easy manipulated in a way to break down the established cognitive patterns and to stimulate new ideas.
- Mental map may play role of a design blueprint helping designers to plan and monitor their design activities.
- Software for mapping should provide a support for a particular mapping approach.
- The concept of ‘site maps’ was introduced and an example was given (Bacardi Web -site)

5.2.1.2.3 Learning

- A balance should be established between constructivism and objectivism educational philosophies and between content-treatment interaction and aptitude-treatment interaction instructional design paradigms.
- Designing an individualised learning environment should take into account learning locus of control, learning styles, problem solving styles and level of prior knowledge of users.
- Users should be able to select from an already available structured content or to construct their own learning content based on a pool of resources. There might be two ways of matching content and learning styles: adaptation and accommodation. According to the first way, learning styles could be identified explicitly in advance and then content adapts to learning preferences. The second approach implies that learning styles are incorporated in a set of options and users selecting one or few of them identify their learning styles.

The same logic might be applied to identification of level of prior knowledge and problem solving styles.

- The content might be studied within the specific patterns of four learning events: explanation, examples, procedures and practice. The learning events may become a basis for identifying implicitly learning styles of people.

The individual constructs to deal with are learning and problem solving styles because they are the most subsuming categories including abilities, cognitive styles and personal traits.

- Problem solving styles might be identified implicitly as the preferences of users to information collection, idea generation, idea selection and idea implementation.
- The learning environment of the SMILE Maker should provide opportunities not only for adapting but also for developing flexibility and versatility of learning styles of users.
- Some functions for monitoring, coaching and providing feedback to users' behaviour could be organised. An idea of designing a personal assistant giving context-sensitive help to users seems promising to invest efforts in it.
- Some metaphors (tailor, cloth shops, and ''prêt-a-porter'') to express the deep meaning of the individualisation of instruction were added to the map.

A set of design specifications was produced based upon the outcomes of the idea generation activities. The next section presents the first specification of the tool.

5.2.1.3 The SMILE Maker - first functional specification

The functional specification of the tool aimed at describing the relationships between the components of the tool and the anticipation how the tool should work. The first specification of the tool includes the following structural components: 'Ideas', 'Profile', 'Maps', 'Method', 'Templates', 'Draw', 'Partner', 'Facilitator' and 'Your Path'.

- '*Ideas'* stands for creative problem solving techniques. They are categorised by the stages of the problem solving process and by some individual characteristics and group dimensions. A user could select a technique (s) from a pool of techniques. A background information (explanation), examples and procedures as a learning events are associated with each of the techniques.
- '*Maps'* stands for mapping approaches. The prototype gives a user the opportunity to select from concept mapping, mind mapping, PERT diagram and flowscape. Background information is available, some examples and procedures are given as well. Users have opportunity to edit map templates.

- '*Profile'* stands for individual differences. The following constructs are available in a pool: cognitive styles (verbaliser/ visualiser; holist/ serialist), learning styles (activist/ reflector/ theorist/ pragmatic), individual traits (introversion/ extroversion/ neurotism; The Big Five Model – neurotism/ extraversion/ openness/ agreeableness/ conscientiousness); locus of control (external/ internal); individual problem solving styles (sensation/ intuitive/ thinking/ feeling); and group member style (task-oriented/ relation-oriented/ self-oriented). The function of 'Profile' can be operationalised by enabling users to get aware of their individual differences, providing them with hints how to optimise the interaction with other variables (matching preferences and creating versatility).
- '*Templates'* include a number of examples developed in different subject matter domains. Some examples of templates are 'Six Thinking Hats', 'System instructional design model', 'Evidence map', 'Force field analysis', 'Causal map', 'SWOT analysis', 'Fish bone diagram', 'Inquiry diagram', 'TO/LOPOSO/GO' diagram. 'Templates' provide users with ready-made diagrams. They could be modified or completely new models could be created.
- '*Method'* presents a strategy based on a combination of mapping approaches and problem solving techniques. The method consists of the following stages and type of maps to be delivered: map information collection, map idea generation, map idea selection, map idea implementation and map contingency plan. The objective of the map information collection step is to map all available information about an issue under study. The problem solving environment is explored in terms of facts and figures. The 'Six universal questions' technique and the lateral thinking techniques of 'Consider All Factors' and 'Other People View' are appropriate to be used here. The objective of the stage 'map-idea generation' is to produce as many ideas as possible for getting a problem solution. The problem solving space is explored in terms of ready-made solutions, proposals and suggestions, new ideas, intuitions, provocation, and hedonistic feelings. Recommended problem solving techniques here are 'How/How Thinking', 'Fantasy Analogy', 'Free Association', 'Random Word', Assumption Reversal', 'Ask Five Times Why', and 'Forced Analogy'. The aim of the map idea selection stage is to choose the most appropriate idea among those already produced during the previous stage. Some techniques such as 'Reverse Brainstorming', 'Plus, Minus, Interesting', and 'Devil's Advocate' might be useful here. The map idea implementation step is aimed at scanning causes, obstacles, and opportunities that could favourably or unfavourably influence the implementation of a problem solution. It is expected that preventive actions would be assigned to each of the negative factors. The 'contingency plan' step operationalises the

problem solution in terms of a sequence of activities and events to present the steps needed to put the solution into practice. The 'Program Evaluation Review Technique' and 'Research Planning Diagram' seem to be the most appropriate for making a contingency plan.

- '*Partner'* is intended to support group problem solving activities. It provides techniques for group problem solving such as 'Brainwriting Pool', 'Collective Notebook', 'Gallery Method', 'Pin Cards', and 'Visual Synectics'. Additionally 'Partner' should support some of the group dynamic processes such as group composition based on problem solving styles.
- '*Draw'* represents the idea of a graphical editor that supports the creation of maps. Some preliminary work was done in the direction of developing a graphical editor but this did not come to a complete workable version.
- '*Your Path'* is to traces the behaviour of users when they explore the workbench of the tool.
- '*Facilitator*' provides some suggestions to users. When gives advises the 'Facilitator' takes into account the stage of problem solving, types of map and a user's profile.

5.2.1.4 The SMILE Maker design model (second specification)

The second specification of the SMILE Maker presents a design model that describe at a conceptual level the main variables and functions that should be taken into account when developing the prototype of the tool. The ideas in the design model were further concretised in development of the SMILE Maker tool (See Section 5.2.2.3). The SMILE Maker design model consists of four components: method, user, learning events, and facilitator. Figure 17 gives a picture of them and their relationships. The design model reflects the goal of the SMILE Maker. The tool is designed to support users to study the SMILE Maker according to their personal preferences. 'Method' describes the purposes, background, and procedures of the four units of the SMILE problem solving method (information collection, idea generation, idea selection, and idea implementation). 'User' focuses attention to the individual differences that may affect learning (learning styles, learning locus of control, problem solving style and level of prior knowledge). 'Learning events' introduces to four different modes of presenting the SMILE problem solving method (explanation, examples, procedures and practice. 'Facilitator' helps users to develop versatile stylistic characteristics and to navigate through the site (profiler, advisor, navigator, and system helper).

SMILE Maker Tool

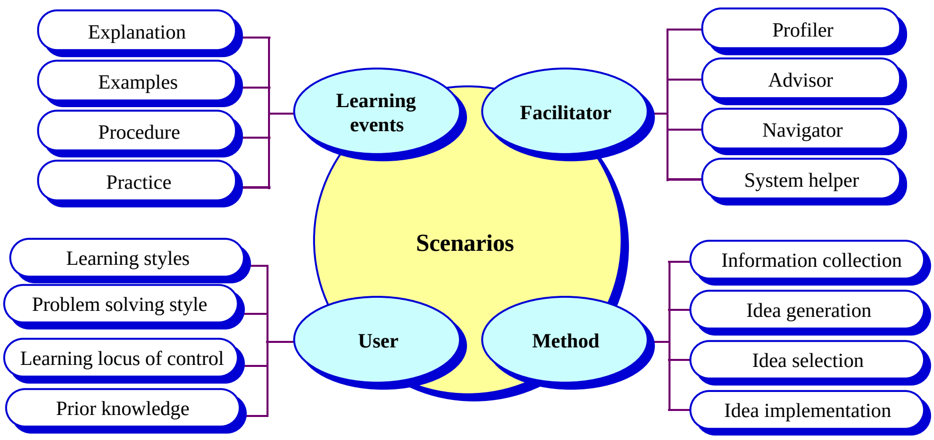


Figure 17. The SMILE Maker Tool design model

The SMILE problem solving method

SMILE problem solving method is a systematic approach that supports elicitation of tacit knowledge, managing individual and group explicit knowledge, development of a versatile problem solving style and overcoming the cognitive overload in the design process. The method capitalizes on the strong points of the rational approaches to problem solving such as explicitness, generality and scientific soundness (Wagner, 1992), but also takes into account the intuitive, non-linear and thinking-while-doing way people approach the problems (Mintzberg, 1992; Schön, 1996, Wagner, 1992). The SMILE problem solving method consolidates the advantages of creative problem solving techniques and different mapping approaches. The method is more that a simple sum of its substantial components. It offers a heuristics approach for managing complexity of design situations increasing the probability of arriving at the most appropriate solutions.

The SMILE problem solving method consists of four types of units: map information collection, map idea generation, map idea selection, and map idea implementation. Each map has a particular purpose and structure.

Map Information Collection

Map information collection explores the problem space for all available data in order to get a broader and more structured picture of the 'what is' problem state. Map information collection is intended to capture the dominant thinking pattern of how one perceives a problem situation. Map information collection facilitates the elicitation of both cognitive and affective components of a personal patterning system. It supports dealing with the 'closure process'. Too little exploration of the problem space might lead to premature closure and too protracted and comprehensive exploration might lead to analysis paralysis.

The information to be collected is everything the problem solver knows or needs to know about the problem situation. This might be either objective data such as facts ("It is the fact...") and statistics ("The figures show...") or 'subjective' data such as a hunch or intuition ("I have a hunch that..."), or analogy and metaphor ("This is like...") or even feelings ("I hate this...").

The way one sees a problem includes also spatial configuration of information. The relationships between items might be descriptive ('is a') or structural ('part of'); causal ('leads to', 'influenced by'); or metaphorical ('like'). These are some suggestions, but the problem solver is free to add other idiosyncratic types of information items and spatial configurations.

Map information collection includes three types of activities - free association, setting relationships and reshaping. The purpose of the first activity is to produce as many items as possible without any judgement or evaluation of the products of this divergent process. ‘Setting relationships’ is about connecting and labelling items, and the last stage – ‘reshaping’ aims at improving the map’s structure after evaluating of the items and the links.

Map Idea Generation

Map idea generation is aimed at generating as many problem solutions as possible. It supports the production of alternative and non-conventional ideas. It is a cognitive tool for the deliberate and systematic braking down of existing thinking patterns. While map information collection takes into account the advantages of the patterning system, map idea generation tries to overcome the disadvantages of the patterning system (See section 2.4 of Chapter 2). Map idea generation provides means for escaping from the dominant ideas of a particular pattern and for manipulating the components of the existing pattern in order to create a new one.

Map idea generation is based upon creative problem solving principles that were discussed in Section 2.5.2.1. Some of them are: changing the perspective, visualising thinking, thinking fluently, creating new combinations, connecting unconnected, tolerating the ambivalence between opposite subjects, using metaphors, deferring judgement when generating ideas, and elaborating on and improving ideas. This stage of the SMILE problem solving method proposes four types of techniques for idea generation*: ‘scratching’* ‘*pairs’*, ‘*hot spot*’ and ‘*labelling’*. Each of them requires both divergent and convergent activities. The problem solver starts with mapping everything that comes to his or her mind, withholding evaluation.

The aim is to create as many solutions as possible postponing judgement about importance or relevance of the ideas. Then the problem solver can converge on producing, analysing the data, grouping and clarifying items to narrow the scope. Each technique finishes with a deliverable – a map of ideas.

Map Idea Selection

Map idea selection has to find the best candidate among the alternatives. It proposes a structured process of putting eventual solutions in order of preference, prioritising alternatives, and selecting the most appropriate solution. Map idea selection distinguishes between possible and feasible. Most of the solutions generated during map idea generation should be considered as possible. During the stage of map idea selection it should be decided which of them seems most feasible to implement. The decision might be taken by the means of intuition, but also it might be a good idea to apply some relatively more objective techniques for handling the uncertainty of a situation. There are at least two ways to do this - appraising a probable solution against established criteria, and considering the possible consequences of implementing a solution. An appraisal criterion is the activity to record first and then to select the criteria against which every option will be checked. Assessing the consequences of a possible course of action involves an estimating the probability to each of them. Some of the probable actions are very certain to happen, others are unlikely to occur. The two fundamental calculations of probability are the probability of success and the balance of risk against reward. All external and internal factors, events or people that may affect the implementation of a solution should be taken into account. It is important to quantify the crucial factors that will work against the solution. The probability of failure calculation will help to make a contingency plan later on.

Either divergent or convergent activities are involved in the map idea selection phase. Divergent activities involve generation of a set of criteria for selection. Free association and postponement of evaluation are important rules to follow. The general principle is to produce as many criteria as possible. Then the problem solver is advised to converge on them in order to narrow significantly their quantity for practical use. Some examples of general criteria might be cost, feasibility, time, or efforts, but users also should look for more specific ones. A criterion might be weighted according to its importance. Each idea then is to be checked against the chosen set of criteria.

Map Idea Implementation

The objective of map idea implementation is to operationalise problem solutions in the terms of a sequence of activities and events. The process involves all the substantial environmental, organisational and personal factors that have crucial role for implementing solutions. Map idea implementation is based upon scientific principles and rational assumptions derived from several analysis techniques such as force field analysis, failure prevention analysis, managing objective and emotional risk analysis, and critical path analysis. Map idea implementation includes activities that capitalise on factors supporting implementation and those that behave against the implementation of a solution. Managing objective risk is about identifying the reasons for risk of failure and making contingency plans. Potential implementation obstacles are listed and preventive actions are developed. An action plan with the necessary steps for putting a solution into practice is also part of this stage. Managing emotional risk deals with all the personal factors resisting implementation. Some of these are perception, personality characteristics, fears, and habits. It is very important to know who will be affected by what and how he or she will be affected being sensitive to other peoples view. Critical path analysis is a technique for planning projects by breaking them into activities and events, and showing their relationships in a network format. Critical path analysis is a plan of action, prioritising the activities which are premises for others. Map idea implementation also combines divergent and convergent activities. Divergent activities are about brainstorming important positive and negative factors, and eventual preventive actions. Convergent activities lead to grouping factors and reducing their number to the most crucial ones for implementing the solution.

The guidelines of the method can be applied in a classical classroom setting, as no mapping software is required. The deliverables of the method could be prepared as drawing on paper, black board or posting 3M post-it notes. When mapping software is available (for example ‘Inspiration’) the procedures of the SMILE Maker problem solving method can be applied using the software as a graphical editor. The graphical interface of ‘Inspiration’ supports the procedures of the SMILE Maker problem solving method. The third option is to work with the SMILE Maker tool. The SMILE Maker tool implements the SMILE Maker problem solving method, provides an access to ‘Inspiration’ and gives an opportunity for learning and applying the SMILE problem solving method in a personal way.

A job aid for the SMILE problem solving method

Table 4 presents a job aid for applying the SMILE problem solving method.

Table 4. The SMILE problem solving method - job aid

	The SMILE problem solving method – job aid
Map information collection	• Try to scan everything you know about the problem situation. Map everything that comes spontaneously and naturally to your mind, as one item is built upon another. Go quickly, without pausing. Just keeping up with the flow of items. The items might be facts, statistics, hunches, intuitions, analogies, metaphors, feelings, and also some existing solutions if any. • Ask yourselves 'when', 'where' and 'how' the problem situation occurred,' and 'who' is involved. Add some new items to the picture. • Ask several times 'why' the problem situation happened, trying to list at this chain all the causes and effects of the problem situation. • Produce as many information items as possible. Impose a quota of about 15 items at least. • Avoid any attempt to judge items during the process of free association. • Make an evaluation trip on the map. Remove or change (if it is necessary) some of the items, and some of the links. Try to improve your map removing all superstitious (unnecessary) items. Change the spatial configuration (if necessary). • Add some new items inspirited by critical overview across items and links. • Try to make clusters of the generated items. Give names of the groups. You may wish to organize the ideas according to the SWOT rule (strengths, weaknesses, opportunities, and threats) or 'Six Universal Questions' (What, Who, Where, When, Why and How). • Draw and label links between items within a cluster. The links might be descriptive ('is a'), structural ('part of', 'belongs to'), causal ('leads to', 'caused by' 'influenced by'), or metaphorical ('like'). Certainly these sorts of links are just examples. More idiosyncratic types of links could be added. • Make labelled links in a similar way between groups of items.
Map idea generation	• Look at the map information collection that has been made. Start to formulate solutions by scratch, as many as possible. Write down everything that pops-up to your mind without any evaluation, or judgement. Try to work quickly. Fix a quota for a number of solutions. There might be minimum up to 10 alternatives. The final deliverable of this sub-stage should be a map of ideas. • Take any pairs of information items preferably from different types ('objective' and

	The SMILE problem solving method – job aid
	'subjective') - metaphors and facts, or statistics and feelings. Again, try to produce as many ideas as you can as they are suggested by a particular combination. Just follow the flow of associations and put them into list without any worry of how relevant to the problem they may be. Fix a quota of 10 alternatives. When you feel that there are not any more ideas coming, take randomly another information pair and repeat the previous step. Three pairs at least should be enough. It is up to you to decide whether to stop or to continue in this way. The general principle is: 'If it is fruitful for you - go ahead'. The final deliverable of this sub-stage is again a map of ideas. • Take randomly one of the marginal (not central concepts) and put it in the very central place of the map. Try to reconfigure the map from this new perspective. Use the new vision as a stimulus for free association in order to generate as many ideas as possible. Put down everything that comes to your mind, withholding judgement. The deliverable to produce is a map containing ideas. • Play with labels. Randomly select a pair of nodes and change the link's label. For instance, 'is a' with 'caused by' or 'like' with 'part of' or just change the direction of causality. All this should be seen as a provocation of your imagination for producing as many solutions as you can. Keep the flow of ideas, writing down everything that pops up to you. Try this approach at least three times. The deliverable should be a map of ideas. • Draw a resulting map containing all ideas generated. Link the nodes and label the links with canonical types you know: 'is a', 'part of', 'like', caused by', leads to', influenced by', and etc. • Try to find any tendency among the ideas you have generated. Is there something in common between them? Is it possible to make clusters? If you find repetition of some of the ideas it should attract your attention. Try to add some more ideas. • The final deliverable of the stage of map idea generation is a structured concept map with solutions that survived the evaluation activities.
Map idea selection	• Start with producing a set of selection criteria. Write down on the list everything that comes to your mind. Put yourself under quota pressure of at least 10 criteria proposals. Work as fast as you can. Keep the flow of suggestions as they naturally come one upon another. Postpone the evaluation for the next step. The deliverable of this step is a list of at least ten criteria. • Look at the list of criteria and choose the most relevant ones.

	The SMILE problem solving method – job aid
	• Make a weighted decision matrix. The first column is for a set of criteria. The second is the criteria importance. Next are the competing solutions. • Rate each of the criterions on importance using a five-point scale (1 - not very important, 5 - very important). • Rate each solution on the extent to which it satisfies each criterion. (1 - low satisfaction, 5 - high satisfaction) • Multiply criteria ratings by the ratings for each solution. • Sum the subtotals of the eventual solutions. • Make your decision. The deliverable of this step is a clear statement about which solution has been selected, and why.
Map idea implementation	• Map down all factors that can negatively affect the implementation of your solution. Free-associate on the issue putting on the map everything that comes to your mind. Try to generate as many items as possible. The deliverable of this step should be a map containing at least 10 factors. • Select the most powerful factors that might inhibit solution implementation. • Make a map with the items that have left after the evaluation. Connect the nodes with appropriate labels ('is a', 'part of', 'caused by', 'like'). • Generate as many approaches as possible to prevent the negative effects of each of those factors. Then select the most promising actions. • Repeat the previous steps but now instead of negative factors consider positive forces that could support implementation. The outcome of this step is a map containing factors that are favourable for implementation of the solution. • Make a map consisting of both positive and negative factors' clusters.

The next three components – ‘learning events’, ‘user’, and ‘facilitator’ are closely related to each other on the purpose to support conceptually designing the learning environment of the SMILE Maker.

Learning events

The idea of the four learning events came as a result of the analysis of different instructional approaches in Chapter 3. The component ‘learning events’ includes four activities - explanation, example, procedure, and practice. ‘Explanation’ could include some definitions, background information, and a theoretical framework. ‘Example’ learning event should refer to some examples, counter-examples, demonstration, simulation and templates. ‘Procedure’ is about a sequence of steps or guidelines to follow. ‘Practice’ is to do or perform something. The four learning events can be recognised as main stages of a general learning cycle. Any sort of content could be studied within a particular sequence of these learning events. The order is not of importance as learning can start from anywhere on the learning cycle. People tend to develop preferences for one of these learning events. They feel more comfortable at one of these stages. The SMILE Maker proposes different formats of these learning events for studying the SMILE problem solving method.

User

This variable gives an idea what are the personal constructs that could affect the way in which users study the SMILE Maker problem solving method and how to deal with this issue. The SMILE Maker builds an individualised learning environment to match learning styles, learning locus of control, level of prior knowledge and problem solving styles. These are the four dimensions of the ‘User’ component.

Four *learning styles* are taken into account: activist, reflector, theorist and pragmatist (Honey & Mumford 1992). Descriptions of those learning styles were given in Section 3.2.2.5. This classification was chosen because of two reasons: a high coefficient of reliability and easy administration of the questionnaire. Chapter 6 provides more detail about the validity and reliability of the learning questionnaire of Honey and Mumford (1992).

The user’s component of the SMILE Maker presumed a strong link between the four learning styles and the four learning events. A Theorist is very likely to choose explanations. A Reflector should look for examples. A Pragmatic should start with procedures, and an Activist should go directly to practice. Based on that, the learning styles could be defined against the four learning events (explanation, example, procedure, and practice styles). People with preferences for explanation learning event like to start with some definitions and knowledge about the theoretical background of phenomena. People with an inclination for examples use examples, counter examples, demonstrations, templates and simulations. A ‘Procedural’ learning style prefers procedures, guidelines and step-by-step approach. ‘Practice’ people prefer to begin immediately to do things. This idea was realised as a design solution in the Tailor-made learning scenario.

Four *problem solving styles* were assumed to exist based on the preferences toward one of the stages of problem solving cycle: seeker, diverger, converger, and practitioner (See Section 2.6.3). Each of the problem solving styles demonstrates a bias to one of the stages of problem solving cycle. 'Seeker' has a preference for information collection, 'Diverger' feels comfortable with idea generation, 'Converger' is strong in idea selection and 'Practitioner' might go first to implementation.

Learning style and problem solving style have been considered as integral cognitive and personality constructs. They are multi-layer categories containing abilities, cognitive styles and some personal dimensions. This should simplify the task of the learning environment designer. The number of personal characteristics to cope with is reduced considerably.

Level of prior knowledge might be low, medium or high. *Learning locus of control* can be defined as a continuum at one extreme of which are people with very high external locus of control and at other are people with very internal locus of control. People with external learning locus of control prefer well structured learning situations in contrast to people with internal learning locus of control who prefer to construct their own learning environments.

The SMILE Maker Tool applies two approaches for matching instructional conditions to learning styles, problem solving styles, learning locus of control and level of prior knowledge: explicit and implicit identification of users' preferences. Users could fill in a special style questionnaire (for example, Honey & Mumford, 1992) or they could simply select options made available on the screen.

Facilitator

The 'Facilitator' is an entity with very important functions for the learning environment of the SMILE Maker Tool. Facilitator has four 'faces' that are complementary to each other - profiler, advisor, navigator, and system helper.

As a *profiler*, the Facilitator identifies, explicitly or implicitly, users according to their learning styles, problem-solving styles, learning locus of control, and level of prior knowledge. As a *navigator*, it gives an idea of how to navigate through the site. It also informs the user about the point she or he has arrived while browsing. As a *system helper*, the Facilitator performs some routine functions on behalf of the system - reminding for saving and downloading procedures. As an *advisor*, it gives some feedback hints to a user based upon two main principles: the completeness of the SMILE problem solving method stages and the completeness of the learning events cycle. 'Facilitator' is designed to support the idea of not only adapting to a particular individual style, but also developing a more versatile style. There are two models behind Facilitator's behaviour as an advisor: a user hypothetical model and a master performer model. In the *user model*, facilitator is designed to initially have an abstract concept about a user. This abstract notion has four attributes: learning style, problem solving style, learning locus of control and prior knowledge. 'Facilitator' makes a judgement about learning style explicitly, and draws an inference about learning locus of control, problem solving style, and level of prior knowledge implicitly. A source of implicit judgement is a selection of scenario in the SMILE Maker Tool. If a user chooses a ready-made scenario, that may means that she or he is predisposed to external learning locus of control. The ‘Facilitator’ concretises the initial hypothesis about a user’s profile on the basis of his or her concrete behavioural traces, making a sort of 'cognitive map'. A very diverse spectrum of user’s behaviour patterns is possible. One can be associated with Theorist learning style, a divergent problem solving style, with internal locus of control and with a low level of prior knowledge. The capacity of the system to make a dynamic profile of a user capturing intra-individual and inter-individual variety of styles should give an idea as how to deal with instability of individual constructs over time, space and task. The opportunity that the system creates for a user to make a choice among several options, also works in this direction. A user could identify her/himself explicitly or the system could make an inference about actual individual preferences interpreting a particular selection of option.

The behaviour of the facilitator as a *master performer* is based on the general principles of completeness of learning events cycle and completeness of problem solving stages. The ‘Facilitator’ gives advices to a user in case he or she skips one or another type of map (information collection, idea generation, idea selection, or idea implementation), or neglects some of the instructional events (explanation, procedures, examples and practice). The ‘Facilitator’ as a master performer gives insight about how to deal with development of versatility and flexibility in learning and problem solving styles.

The four main components of the SMILE Maker design model build specific patterns within the framework of four learning scenarios. They will be described in more detail in Section 5.2.2.3.1.

5.2.2 SMILE Maker – task space

The purpose of the task space is to develop and formatively evaluate a partial product. The project adopted prototyping as a development methodology. Prototyping is defined as building a working version of the design model of a particular system to check some assumptions in advance before developing a final product. It is considered to be a reliable way of validating the design ideas. A common classification distinguishes between throw-away prototypes, evolutionary prototypes and incremental prototypes (Cotterell & Hughes, 1996). The SMILE Maker Tool is an evolutionary prototype in the sense that it has been developed gradually, improving its functionality after some formative evaluation and reflection-in action.

The prototyping activities of the SMILE Maker included three types of deliverables: storyboarding (Section 5.2.2.1), mocking up (Section 5.2.2.2), and the SMILE Maker prototype (Section 5.2.2.3).

5.2.2.1 Storyboarding

The concept of storyboarding has been borrowed from the movie industry. It shows what the sequence of the computer's screens will be and how they should look. Storyboarding gives an initial idea about the structure, functionality and interface of the program. In addition it indicates what text, images and links will be applied in the real computer program. Storyboarding provides opportunity for additional idea generation in the beginning of the implementation phase. This procedure reduces the probability of committing mistakes later on in the development phase. In the current project storyboarding was carried out sketching the specifications of the SMILE Maker Tool on sheets of paper. During the storyboarding more ideas about the functionality of the SMILE Maker were generated.

5.2.2.2 Mocking up

A mock up of the tool aimed at supporting the educational problem solving was developed on the basis of the specification and storyboards. The mock up was built to check some of the ideas about the functionality and the interface of the tool. It is a standalone product programmed in Delphi 4 language[1].

A small-scale formative evaluation of the mock up was conducted in order to get some feedback about the realisation of the design ideas and eventual improvement of the tool. Five experts with different profiles took part in this formative evaluation. Three of them were educational technology experts and two were computer science experts. Three qualitative data collection methods were used: analysis of the documentation, software walkthroughs and semi-structured interviews. The evaluation procedure included the following steps:

- The specification of the prototype was sent to the experts.
- In a specially arranged session the functionality and the interface of the tool was demonstrated. The experts got an opportunity to go through the product.
- A discussion was organised on the basis of a semi-structured interview. Four types of questions classified under the headings of 'general', 'problem solving method', 'learning method' and 'interface' were prepared in advance. A question defined as 'general' was

[1] All the work on the mock-up was lost when my computer crashed. A screenshot is available but with bad quality.

"How relevant is the realisation of the design ideas in the prototype?" An example of a question about problem solving method was "Can this method help in solving educational and training problems?" There were several questions related to the learning method implemented in the tool. For example: "What do you think of the idea of studying the method within the sequence of four learning events of explanation, examples, procedures and practice?" One of the questions reflecting the interface of the tool was about the role of 'Your path'. The questions in the semi-structured interview were prepared just to give direction to the session. Many other questions appeared during the discussion. The raw data from the interviews consisted of notes taken by interviewer. After the interviews the data were analysed by combining them and looking for some patterns. The main suggestions could be summarised as follows:

- The conceptual design of the Brain Map was adequate to support people in solving design problems.
- The design solutions appeared relevant for the purposes of the product.
- More elaboration on the problem solving part and especially on the learning part of the tool was needed in order to see how the design solutions work in practice. In the mock up the functionality was not sufficient to say much about the eventual capacity of the tool.
- It was not clear how the idea of matching learning locus of control and level of prior knowledge was to be realised.
- The functionality of the option of 'Profile' was not enough operational. The function of the 'Facilitator' should be developed in more detail.
- The structure, interface and functionality of the tool suggest a Web application. Some of the arguments for this are described as follows:
  - Users can access the tool receiving just in time, just enough and at the point of need support.
  - Users can proceed through the tool in their own pace and place.
  - Web applications can be accessed by Web browsing software on any platform.
  - Web applications can be accessed from any computer in the world.
  - The content can be easily updated and made immediately available to everybody everywhere.
  - The Internet gives direct access to a vast library of resources to enhance learning.
  - The Web provides opportunities for different and flexible forms of communication.

- o There was a suggestion to select an already available commercial graphical editor instead of developing a new graphical editor.

The formative evaluation of the mock up provided room for further improvement of the tool. The next section 5.2.2.3 introduces to the SMILE Maker prototype.

5.2.2.3 The development of the SMILE Maker prototype

The SMILE Maker prototype is more operational than the mock up as additional functionality was built up. A functional flowchart (See Appendices 1 and 2) is a representative for a part of the structure, functionality and navigation of the tool). The main contributions to the functionality are as follows:

- It is a web-based tool.
- A considerable improvement of the learning environment is made, as the concept of learning scenario was operationalised in some design solutions.
- The complete functionality of the 'Facilitator' is developed.
- A supportive web site is developed.

5.2.2.3.1 SMILE Maker functionality

There are five main options in the SMILE Maker (http://projects.edte.utwente.nl/smile/HomeSite/): 'Introduction', 'Guide', 'Scenarios', 'Resources', and 'Partner' (See Figure 18).

Figure 18. The SMILE Maker - Introduction

'Introduction' provides a user with knowledge of what the SMILE Maker Tool is about – purposes, functions, and architecture. 'Guide' gives an impression of the structure of the tool. There is brief information about each of the components - introduction, scenarios, resources and partner. The information is presented in two ways: visually via a 'The Brain' map and verbally with a simple description of the functions. Users are able to play with the map to see the structure of the site (See Appendix 8).

The idea behind 'Resources' was to support people if they want to know more about mapping and problem solving apart from the SMILE problem solving method. The information in 'Resources' was divided into four main parts: techniques, mapping, software, and templates. They provided links to external Web sites. 'Techniques' represents problem solving principles and methods. 'Mapping' includes different mapping approaches. 'Software' presents mapping and problem solving software. 'Templates' are visual examples of how methods, techniques and software have been used in a large scope of problem domains.

'Partner' is to fix the idea of supporting group problem solving through mapping approaches. Basically the SMILE Maker is an individual problem solving and learning tool. 'Partner' emphasizes the need for further work to apply the SMILE problem solving method and learning environment in the context of group problem solving.

Figure 19. The SMILE Maker - Scenarios

Studying and applying the SMILE problem solving method is accomplished within the structure of four learning scenarios. They were composed as specific combinations of the

SMILE Maker design model components (method, user, learning events and facilitator). The four scenarios are ready-made, tailor-made, self-made and atelier. The metaphor-based names should give an indication of the purposes and the content of the scenarios. The metaphor-based names of the scenarios were developed in a relatively later stage being an illustration of the process of reflection-in action. The initial names were tutoring, adaptation and laissez-faire. The front page of the scenarios explains the purpose and the background of each of the scenarios. Based on that a user can select one of them depending on his or her learning locus of control. Figure 19 shows the 'Scenarios' front page.

Ready-made scenario

The *Ready-made* scenario (See Figure 20) is designed for the people with an external learning locus of control that like to have a well-structured learning environment and to follow instructional prescriptions. The units of the SMILE problem solving method are considered in predetermined order. Each type of map (information collection, idea generation, idea selection and idea implementation) is presented within the sequence of the four learning events (explanation, examples, procedures and practice). Users begin with explanation about map information collection, and then procedures and examples are given. Explanation describes the objectives and the theoretical background of map information collection. 'Procedure' provides a step-by-step approach for applying the guidelines of map information collection. 'Examples' gives an example of map information collection. When users reach the 'practice' learning event, they are invited to apply what they have learned about map information collection. The SMILE Maker Tool proposes a graphical editor ('Inspiration'). It can be opened if it is installed on the hard disc of a user or it can be downloaded.

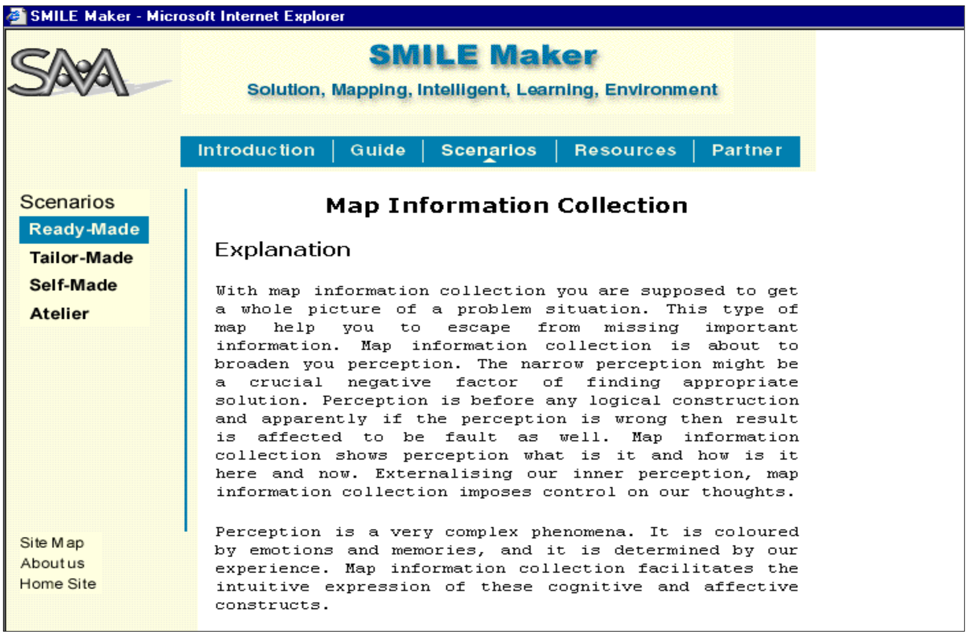


Figure 20. The SMILE Maker - Ready-made scenario

The same logic of presenting is applied for the other types of maps – idea generation, idea selection, and idea implementation.

Tailor-made scenario

The *Tailor-made'* scenario (See Figure 21) is aimed at providing instruction according to in advance and explicitly defined learning styles. Users study the SMILE problem solving method in different way depending on their learning styles. This scenario is designed for people that prefer to be guided but the instruction is predefined according to their learning preferences. In the 'Tailor-made' scenario users could first identify themselves according to one of the four learning styles - activist, reflector, pragmatist and theorist (Honey & Mumford, 1992). This could be done in two ways: via learning style description or via scores on learning styles questionnaire (Honey & Mumford, 1992). In the learning styles description each of the learning styles is presented in one paragraph. The learning style questionnaire consists of 80 statements indicative for the four learning styles. The learning styles questionnaire is offered for people who are not sure what learning style they are and for whom the short descriptions are not sufficient. No matter what option for learning style identification is chosen, the system uses the input data from the learning styles questionnaire or learning style descriptor page to send users to a specific pattern of the content (The SMILE Maker problem solving method) matching their learning styles.

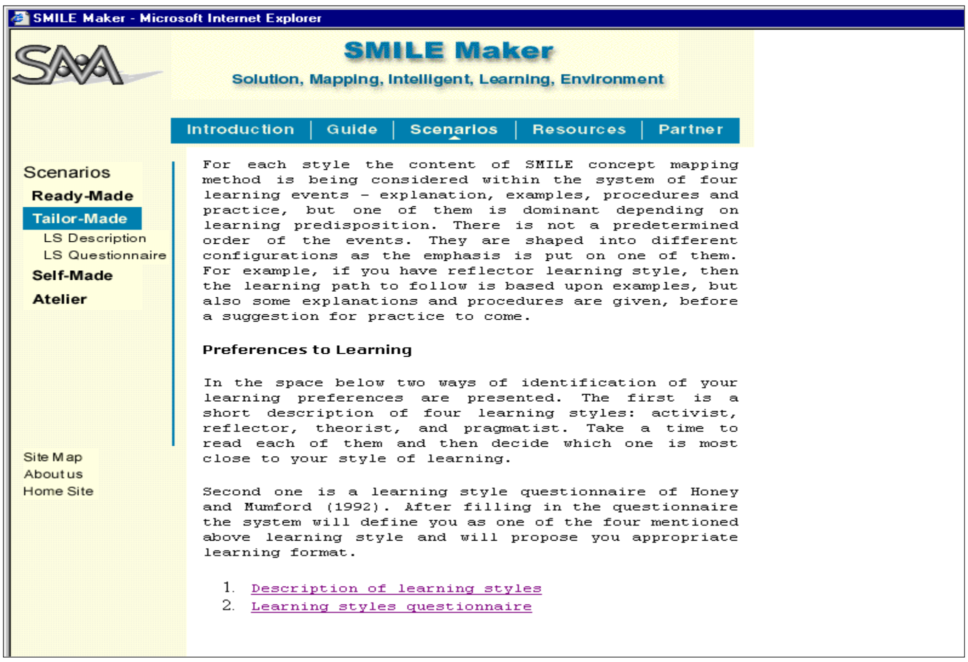


Figure 21. The SMILE Maker - Tailor-made scenario

This design solution is based on two ideas: the relationships between the four learning styles and the four learning events, and developing instead of adapting to learning styles of people.

For example the pattern for a reflector is based predominantly on examples, demonstrations and templates, but he or she also gets some explanations and procedures, and also is invited to practice. The dominant learning event for an activist is practice, for theorist – explanations and for pragmatist – procedures and guidelines. The design solutions in the tailor-made scenario support the idea of not only adapting instructional conditions to a particular learning style but also developing more versatile styles. While holding on the strong points of a particular style, the system develops the users' week stylistic characteristics. Appendices 9 - 11 give more views on this scenario.

Self-made scenario

The sources of variation in '*Self-made* ' scenario (See Figure 22) are both the 'SMILE method' and 'learning events'. There is not a predefined sequence of problem solving maps. However, the content for studying is still the SMILE problem solving method. A user can start any of the stages of the SMILE problem solving method and then can select any of the instructional events. There are two hypotheses here. Firstly, a user has a high level of knowledge about the method and he or she needs only particular information. Secondly, a user has a low level of prior knowledge, but the locus of control is internal. In this case the user prefers to study SMILE problem solving method within a not very much structured learning environment. Learning events are designed to be self-contained. If for example a user selects procedures learning event then he or she will have in addition some background information and examples incorporated within the procedures. Appendices 12 and 13 show pictures of the self-made scenario.

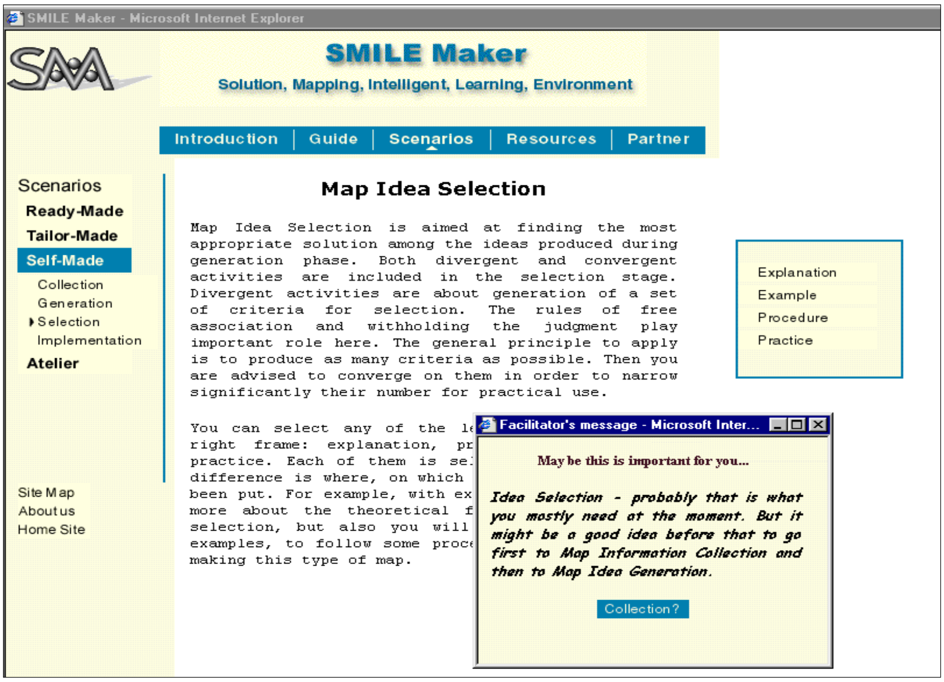


Figure 22. The SMILE Maker - Self-made scenario

Atelier scenario

The '*Atelier*' scenario (See Figure 23) attempts to support people who are confident in building up their own method for problem solving based on mapping and creative problem solving principles and techniques. There are several components a user could select from: ideas, maps, software and templates. 'Ideas' contains short information and links to external sites about problem solving process, brainstorming rules and guidelines, and problem solving techniques. 'Maps' is about different mapping approaches – theoretical framework, procedures and examples. 'Software' presents links to sites that promote mapping and problem solving software. 'Templates' provides external links to Web sites where visual examples are developed. Appendix 14 presents another screenshot from this scenario.

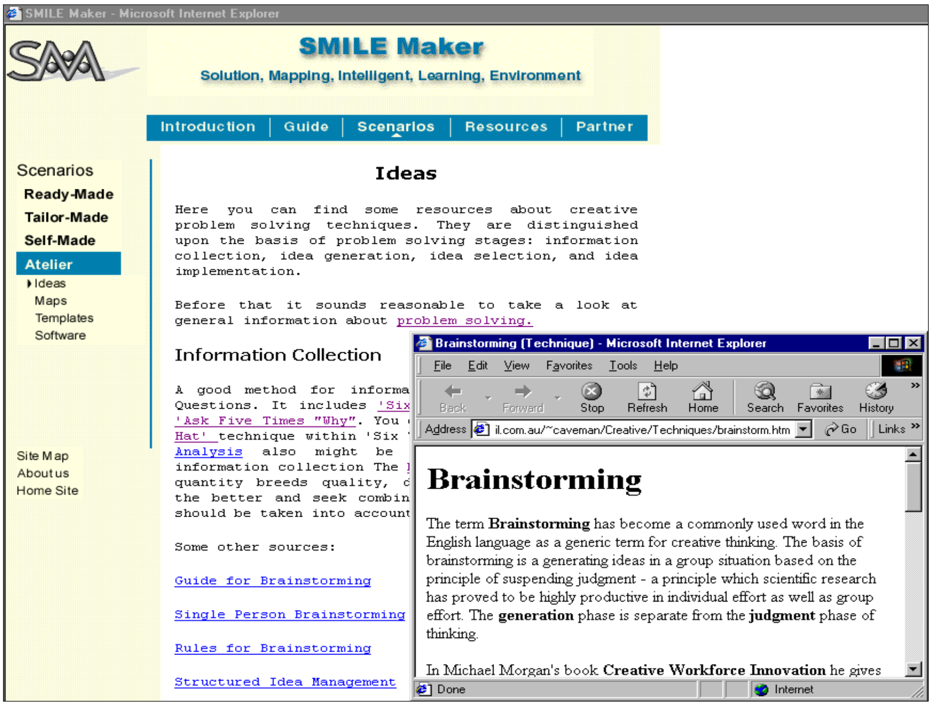


Figure 23. The SMILE Maker - Atelier scenario

5.2.2.3.2 Facilitator

When browsing through scenarios a user may encounter messages from the facilitator with some suggestions and hints what to do. The messages of the facilitator take the form of a pop up window (See Figure 22). Usually this appears when a problem solver has missed a stage in the problem solving process or a learning event. The idea of this sort of physical appearance of the facilitator came up as a reflection-in action, while improving the design of the tool. Some options were considered, for example, a moving text on the line bar or a static personal assistant. The choice of pop-up window was made because of two reasons. Firstly, it prompts the attention of a user. Secondly, its appearance follows a particular behaviour of a user.

Users can benefit from another function of the facilitator as well. A navigation window shows dynamically where they are in the site at any particular moment. Selecting an option immediately reflects changing the configuration of this navigation window showing the point at the site at which a user is. The navigation window is a further development of the idea of 'Your path' in the mock up.

5.2.2.3.3 The SMILE Maker supportive web site

The SMILE Maker supportive web site (See Figure 24) was develop as a response to the requirements of users for more explicit information about the theoretical background of the SMILE problem solving method and the SMILE Maker tool. The purpose of the supportive web site is to introduce users to the objectives, background, structure, and the functionality of the SMILE Maker tool. The supportive web site consists of the following options: theoretical background, system model, structure, and a link to the SMILE Maker tool. 'Theoretical Background' discusses the underlying rational of the tool. Three theoretical perspectives were introduced here: instructional paradigms, mapping approaches and problem solving techniques.

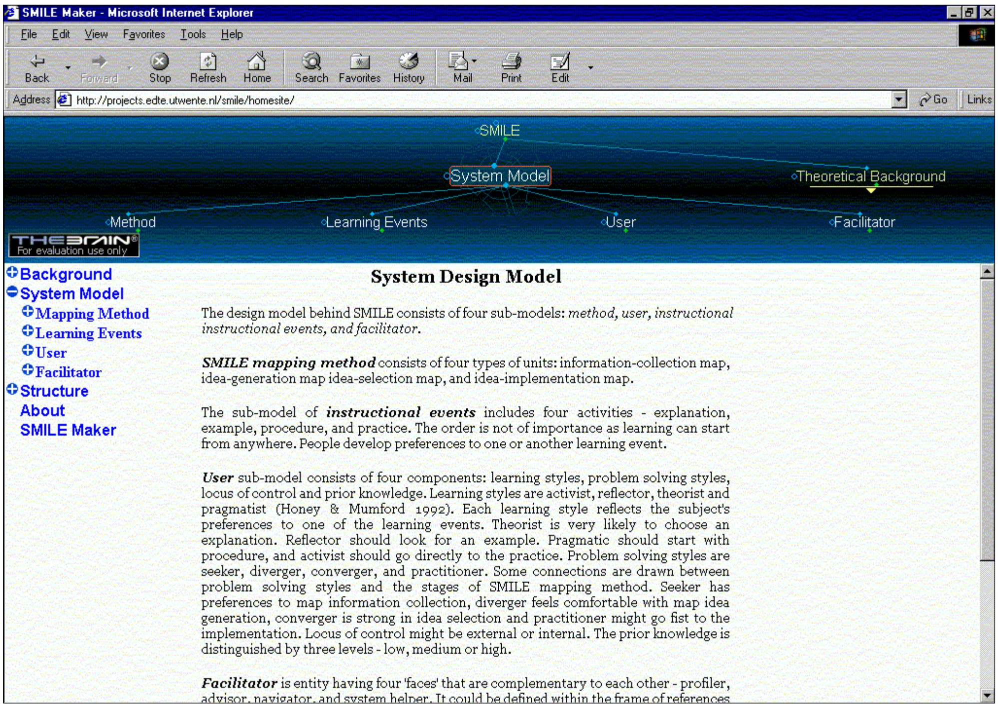


Figure 24. The SMILE Make supportive Web site

'System model' presents the design model of the SMILE Maker tool. 'Structure' gives information about the main components of the SMILE Maker tool: Introduction, Guide, Scenarios, Resources and Partner. The graphical interface of the SMILE Maker supportive site includes a site map based on 'The Brain' technology. It was designed to make the navigation through the site easy. There was also a mutual co-ordination between site map and the left navigation frame. Users could select which of the options to follow. The assumption is that the verbaliser type of user would navigate through the left frame while visualisers will navigate through the site map. Whatever option is selected, changes in one of them reflect changes in the another. There is a link to the SMILE Maker introduction page. Appendices 3-6 show more views on the SMILE Maker supportive site.

5.2.3 SMILE Maker - implementation space

SMILE Maker tool proposes several options for end users to adapt the tool according to their needs. Firstly, they could select a learning scenario to build their own learning environment. Secondly they could develop their own problem solving method based on mapping and problem solving either choosing the Atelier scenario or resources. Thirdly, end users are free to select a graphical editor or word processor, which they are mostly familiar with. Fourthly, the SMILE problem solving method is generic enough to give users a flexible framework to elaborate on the method or modify it according to their specific domain of expertise.

5.3 Summary

This chapter presented the transformation of ideas about problem solving, mental mapping and learning discussed in the chapters 2, 3 and 4, into design solutions of the SMILE Maker tool in order to meet the challenges of improving the educational and training design process. The process of designing and developing the SMILE Maker tool was interpreted within the framework of 3-Space Design Strategy (Moonen, 1999, 2000, 2001). It consists of three design spaces: consensus, task and implementation. The chapter reported on three activities of the consensus space: information collection, idea generation, and functional specification. During the task space a mock up and the SMILE Maker prototype were developed and formatively evaluated. Implementation space discussed the possibilities that the SMILE Maker provides for a customisation of the tool.

Chapter 6. Methodology of the SMILE Problem Solving Method and the SMILE Maker Tool evaluation

This chapter aims at providing information about the research methodology of the study. The chapter reflects the research question '*What is the research methodology for the SMILE problem solving method and the SMILE Maker tool evaluation?*' The concept of triangulation constitutes the basis of the SMILE Maker evaluation methodology. The chapter begins with a definition of triangulation from a research methodology perspective (Section 6.1). Then an interpretation of the concept of triangulation used in this study is given (Section 6.2). The meaning of the triangulation is presented as variations in research paradigms, evaluation subjects, data collection methods, measuring instruments, and data analysis techniques.

6.1 What is triangulation in research?

The methodology of the SMILE problem solving method and the SMILE Maker tool evaluation is based on the concept of triangulation. Triangulation is a combination of variety of research approaches, methods, data sources, instruments, statistical analysis and theories for arriving at a high level of validity and reliability of a study. Patton (1990) defines four types of triangulation: methods triangulation, triangulation of sources, analyst triangulation and theory triangulation. He describes in more detail the meaning of triangulation in the social research domain as follows:

- *Triangulation of methods*. It involves comparing the data collected by qualitative methods and data collecting by quantitative methods in order to converge the findings. However Patton tries to prevent from illusion that the results generated by different methods will automatically come together as an integrated whole. He predicts some initial conflicts between the findings. Patton concluded, "the preponderance of judgement by experienced researchers is that it is worth doing – it is worth using multiple methods, comparison analysis, and convergent validity checks to enhance the quality and credibility of findings" (Patton, 1990, p. 465).
- *Triangulation of data sources*. It means using and cross-checking different sources of information: interview, observation, and survey, for example. According to Patton "consistency in overall patterns of data from different sources and reasonable explanations for differences in data from divergent sources contribute significantly to the overall credibility of findings".

- *Triangulation through multiple analysts*. This implies involving different observers, interviewers, and analysts in order to reduce the biases of researches and check the reliability and validity of the data. A variation of this type of triangulation is the involvement of those who were studied to review the findings or read and react on a report or paper concerning the data.
- *Theory triangulation*. It involves using different theoretical frameworks to explain the same data. Specific forms of this type of triangulation are looking for rival explanation and examining the data from the perspective of different stakeholders.

Triangulation in the way it was defined by its four meanings is an ideal construct. Applying the all meanings of triangulation in an evaluation process does not seem feasible. We should construct a practical meaning of triangulation taking into account all the specifics and constraints of a particular research.

6.2 The concept of triangulation used in the SMILE problem solving method and the SMILE Maker evaluations

The evaluation of the SMILE problem solving method and the SMILE Maker will be based on a pragmatic interpretation of the concept of triangulation. This involves combining the following components of the evaluation research: different research methodologies (Section 6.2.1), different target groups (6.2.2), data collection method (6.2.3), research instruments (6.2.4), and data analysis approaches (6.2.5).

6.2.1 Different research methodologies

Quantitative and qualitative research paradigms are two dominant alternatives but not mutually exclusive research methodologies. They both have advantages and disadvantages. Quantitative research could measure the reactions of a great number of subjects with standardised evaluation instruments, thus making reliable comparisons and statistical aggregations. It can yield a broad and generalisable set of findings. By contrast qualitative methods typically produce detailed information about much smaller sample of people and cases. They increase the depth of understanding but reduce the generalisability. Quantitative methods could improve the breadth of the research while qualitative methods could improve the depth of the research. Qualitative methods are strong in reporting the internal validity of the research while qualitative methods contribute to the external validity of research. Ideally an evaluation should combine the advantages of both quantitative and qualitative research paradigms. In the evaluation of the SMILE problem solving method and the SMILE Maker both quantitative and qualitative research approaches are applied. Two experiments as representatives of quantitative approaches were conducted (See Chapter 7 and 8). Different formats of expert focus group interviews and observations are the representatives of the qualitative research approaches applied in the current study (See Chapter 7 and 8).

6.2.2 Different target groups

As far as the SMILE problem solving method and the SMILE Maker tool addresses a broad audience of users in the terms of subject matter domain and level of expertise, their evaluation need to be done with an attempt to cover as broadly as possible the target population. Firstly, the target groups differ on level of expertise as either students or experts can take part in the evaluation of the SMILE problem solving method and the SMILE Maker. Secondly, the subjects were selected from different fields of expertise such as educational and training design, creative problem solving, consulting methodology and software engineering. The subjects taking part in the evaluation of the SMILE problem solving method and the SMILE Maker tool are listed as follows:

1. Students with different academic orientation located at different places (Faculty of Educational Science and Technology and Faculty of Technology and Management, University of Twente (The Netherlands); Faculty of Psychology and Educational Sciences, Free University of Brussels (Belgium); Faculty of Mathematics and Informatics, Sofia University; Faculty of Management at the University of Management and Economics (Sofia, Bulgaria). In the experiment conducted to validate the SMILE problem solving method mainly students from the faculty of Mathematics and Informatics were involved. The students from other institutions took part in the experiment aimed at evaluating the performance effectiveness of the SMILE Maker tool. More information about the sampling is given in Chapters 7 and 8.
2. Different profiles of experts. Experts participated in the evaluation of the conceptual model of the SMILE problem solving method and in the evaluation of the SMILE Maker tool. The typology of the experts involved in the study is as follows:

- University instructors from the following domains:
  - Educational and training design (Faculty of Educational Science and Technology, University of Twente)
  - Engineering design and creative problem solving (Faculty of Management and Technology, University of Twente)
  - Software engineering design (Faculty of Computer Science)
  - Educational research (Faculty of Psychology and Educational Science, Free University of Brussels

  - Organisational strategy; marketing; total quality management and learning organisation (Faculty of Business Studies, Salford University, UK)

- Kreanet: a network of academicians and consultants in the field of creative problem solving in the Netherlands and Belgium.
- Specialists in knowledge management (‘Ikhaya’ – a company for producing tools for knowledge management, located in Deventer, the Netherlands)
- Experts in marketing and customers research (Unilever – a company located in Vlaardingen, the Netherlands.

6.2.3 Methods.

Several research methods were applied: experimental method (Section 6.2.3.1), expert focus group interviews (6.2.3.2), prototyping (6.2.3.3) and observation (6.2.3.4).

6.2.3.1 Experimental method

Two experiments with students were conducted in the framework of the current research. The first one was intended to verify the SMILE problem solving method via paper-pencil exercises without using any mapping software. It applied a factorial (2 x 2) experimental design with a post-test-only control group. The two independent variables were ‘method’ with two levels (SMILE problem solving method and the classical concept mapping method), and ‘learning styles’ with two levels (Doers and Thinkers). General and interactive effects were measured on the dependent variables of mapping production after solving a case. The second experiment used randomly assigned experimental and control groups with a post-test only experimental design. The experiment was aimed at getting data for the performance effectiveness of the SMILE Maker and attitudes of students toward the tool. The independent variable was ‘tool for solving problems’ with two levels (the SMILE Maker Tool and the Mind Manager) and three dependent variables (solution of a case, mapping production, and perceived problem-solving effectiveness reported on a reflective questionnaire. The independent variable was controlled for the effect of some mediator variables such as learning styles, learning locus of control and problem solving styles.

6.2.3.2 Expert focus group interviews

A focus group interview is an interview of small group of key informant people. In relatively short period of time (from half of hour to two hours) valuable information could be collected. The social context of the discussion between group’s members has a potential to enhance the quality of collected information (Paton, 1990). The first focus group interview was organised in a format of a workshop within the framework of the conference ED-MEDIA 1998 in Freiburg (Germany). We took the opportunity provided by the conference to propose a workshop about concept mapping with an idea to get some reactions to the SMILE problem solving method. The most of the experts who chose to participate in this workshop were educational technologists. The second expert focus group interview also took the opportunity created by the conference 'Information Society Technologies' (Sofia, Bulgaria, July, 1998) for organising a workshop. The workshop included as participants students and experts in information technologies, educational and training design, and philosophers. More information about the participants, procedure and the results of the two workshops is given in Chapter 7. Several expert focus group interviews were organised in the Year 2000 with experts having different profiles. The variation included educational and training design instructors, educational research instructors, software engineering instructors, organisational strategy and learning organisation instructors, consultants in creative problem solving and innovation, knowledge management specialists, and customer behaviour study specialists. Chapter 8 provides more detail of these.

An important consequence of using this data collection method is that some expert focus groups could be considered as negative cases. Disconfirming cases could challenge the main assumptions in a particular construct but the attempt to solve contradictions or to deal with the challenge may help in validating a specific approach. Disconfirming cases are considered as "a source of rival interpretations as well as a way of placing boundaries around confirming findings. They may be "exceptions that prove the rule" or exceptions that disconfirm and alter what appeared to be primary patterns" (Patton, 1990, pp. 178, 463). In this study two negative sampling cases are identified but within the framework of the SMILE Maker evaluation they should not be described as disconfirming. As attitudes of participants they are negative but as a consequence they were confirmatory cases in respect to the main assumptions of the study. The two negative cases in the SMILE Maker evaluation were not intentionally organised. They just occurred. At the beginning of collecting data, they were considered as something that had to be dropped out being not relevant to the objectives of the study. However, the discussions brought some interesting ideas, which were in the line with the findings of the study.

The first negative case was a group of philosophers taking part in the conference 'Information Society Technologies' (Sofia, Bulgaria, 1998). Although, the atmosphere was not favourable for an unbiased evaluation of the SMILE problem solving method, the discussion consolidated the theoretical background of the method. In addition the idea of heuristics was reconsidered. At the beginning of designing the SMILE problem solving method the heuristics were ruled out as not relevant to the ‘managing complexity’ approaches. More information about this case is given in chapter 7.

The second negative case constitutes a group of Ph.D students in economics at Salford University (UK, 2000). There was an ironic question such as “Can SMILE Maker solve the problem of a world economic crisis?” The quick answer could be: “Certainly not. It was not supposed to do that”. However, during the discussion, by hitting back some questions to the participants some interesting facts were revealed that could be interpreted in favour of the ideas behind the SMILE Method. It turned out that some countries had found a way to solve the problem in a considerably more quick fashion than others. They approached the issue not in a traditional way, but organised special task force groups, which applied some problem solving techniques to structure their activities.

The experts’ groups could be considered as positive cases in some aspects and as negative cases in some other aspects. For example the high level expertise of consultants in the field of problem solving methodology is combined with an intuitive understanding of the processes of learning and instruction.

6.2.3.3 Prototyping.

A full functioning prototype of the tool called ‘SMILE Maker’ was designed and developed during the study. Prototyping is defined as “a process of building a working model of the system…to obtain an early version of a product or a system” (DeGrace & Stahl, 1990, p. 126). Some authors (Cotterell & Hughes, 1996) distinguish between the following types of prototypes: throw-away prototypes, evolutionary prototypes and incremental prototypes. Other prefers rather to assign roles to prototyping (Budgen, 1994) such as evolutionary, experimental, and exploratory. The second approach seems more flexible because different roles can be attached to one prototype. The SMILE Maker is an evolutionary prototype in the sense that it has been developed gradually to a final product improving its functionality after each formative evaluation. As a prototype the SMILE Maker tool could be described within the framework of the development research paradigm (Akker, 1999; Moonen, 1999; Richey & Nelson, 1996). At the same time The SMILE Maker could be considered as a hypothetical construct, applying a design model. In this sense the tool has an experimental role (Budgen, 1994) to check the validity of some ideas.

6.2.3.4 Observations

Observations provide firsthand experience in terms of what is happening in a particular field and who is taking part in this. An observation should register reality as much close as possible. There are different types of observations: participant observation, field observation, and direct observation (Patton, 1990). As was reported in Section 1.1.3 a direct observation of the behaviour of students in the course ‘Linear & Hypermedia’ was conducted.

6.2.4 Instruments

Both standardised and constructed research instruments were used in the current study. For identifying the learning styles of students in the framework of the experimental verification of the SMILE problem solving method, a standardised learning style questionnaire (Section 6.2.4.1) was administered (Honey & Mumford, 1992). In addition three more measuring instruments for the purposes of the current research were constructed and checked against reliability and internal validity: reflective questionnaire (Section 6.2.4.2), style inventory (Section 6.2.4.3), and mapping production (Section 6.2.4.4).

6.2.4.1 Honey & Mumford Learning Style Questionnaire

This instrument divides people into four learning style categories: Activist, Reflector, Pragmatist and Theorist. Honey and Mumford reported a coefficient of reliability of .89. (Pearson's product-moment of correlation) The questionnaire had been validated across 3500 people in UK and general, and some specific occupational norms have been established.

6.2.4.2 Reflective Questionnaire

The reflective questionnaire aims at registering the reflections of the experimental subjects on how they applied the SMILE Maker and the Mind Manager tools for solving an ill-structured case. The reflective questionnaire consists of three scales: ‘method’, ‘learning environment’ and ‘interface’. The reflective questionnaire was tested with 32 subjects for reliability. Initially the value of this coefficient of reliability was .86.4 (Cronbach’s alpha). The questionnaire was improved within a framework of a students’ research assignment (Smits, & van Dijk, 1999). The coefficient of reliability was improved slightly - Cronbach’s alpha =.88.

6.2.4.3 Style Inventory

The Style Inventory is the second constructed instrument in the study. It measures learning locus of control, learning styles and problem solving styles. The instrument was used in the second experiment conducted to show the performance effectiveness of the SMILE Maker Tool. The Style Inventory was tested in advance with 38 subjects from the Faculty of Management and Technology, University of Twente for construct validity. Convergent validity was calculated as the correlation between the measurements of the same construct with different techniques (Style Inventory and a questionnaire supporting the report of the experimental subjects on their behaviour when using the SMILE Maker). The convergent validity of the three constructs are relatively high according to Persons's Correlation: problem solving style: .371 (p<.05), learning style: .356 (p<.05), and learning locus of control: .335 (p<.05). The discriminant validity of the Style Inventory was tested as a correlation (Pearson's Correlation) between the three different constructs measured by the instrument. The value of the correlation for the three constructs was relatively low: problem solving style and learning style: -.063, problem solving style and locus of control: .272, and learning style and learning locus of control: -.052.

6.2.4.4 Map production

Map production also was used as a measurement instrument as well. The scoring scheme of map production is based on the suggestions reported by Novak and Gowin (1984) and Novak (1998) in scoring concept maps and the criteria for creative thinking developed by Guilford (1967). The scheme takes into account the specific purposes and functions of the SMILE problem solving method. The scoring scheme is based upon the criteria of broad perception, divergency, convergency and planning. Each of these is operationalised by a set of indicators as follows:

- *Broad Perception*: fluency (number of nodes; number of links); flexibility (variety of nodes - facts, data, personal (see Table 5 and Appendix 19) experience, opinions, feelings, assumptions, metaphors & analogies; variety of labels - descriptive, structural, causal, interrogative, remote associations; variety of links - one-directional, bi-directional, cross-links)
- *Divergency*: fluency (number of ideas); flexibility (variety of ideas - ready-made solutions, elaboration, suggestions, unusual ideas)
- *Convergency*: Inverse fluency (reducing to one best idea, reducing to a few ideas arranged in consequence, reducing to a few ideas arranged by importance, reducing to a few ideas, not arranged, no idea selected at all)
- *Planning*: The extent to which the solution is presented in the terms of a sequence of activities and events (consequence, system, 'PERT' formats, no planning).

This scoring scheme was applied in the experiment for validating the SMILE problem solving method. It will be presented in Chapter 7. The coding scheme was elaborated slightly for the purposes of the experiment aimed at evaluating the SMILE Maker tool. It will be discussed in Chapter 8.

6.2.4.5 Data analysis approaches

The study applies analysis of variance, regression analysis, and correlation analysis. In the first experiment two-way analysis of the variance was used as the most appropriate statistical technique for the factorial experimental design. In the second experiment one way analysis of the variance was used for measuring the main effect of the independent variable on the dependent variables. Regression analysis was applied to control the interaction effect caused by the mediator variables. In the second experiment a correlation analysis was used as well.

A number of qualitative data analysis techniques were also used (scripting, pattern coding, and memoing). Scripting captures recorded data keeping the authentic way in which interviews has been hold. Scripting is followed by first-level coding for summarising the segments of data. “Pattern codes are explanatory or inferential codes, ones that identify an emergent theme, configuration or explanation.” (Miles & Huberman, 1994). Memo is usually an idea (or ideas) that comes up during coding in order to connect several codes in a meaningful way. Memos could be a sentence, a paragraph or few pages. Scripting, coding and memoing were applied in the analysis of the focus-groups interviews.

6.3 Summary

The objective of this chapter was to describe the research methodology of the study. The concept of triangulation was introduced as the theoretical background of the methodology. For the purposes of this study triangulation was operationalised as a variation of research approaches, types of evaluation subjects, research instruments, data collection methods and data analysis techniques. The current project applies both qualitative and quantitative research approaches. Students with different academic orientation and experts with different profiles participated in the research. The study includes two experiments, a number of expert focus group interviews, prototyping and observations as data collection methods. It applies a standardized learning style questionnaire and several other research instruments were constructed (reflective questionnaire, style inventory and mapping production scoring scheme). Some inferential statistics such as one- and two way analyse of variance were used in the study as data analysis techniques. In addition some qualitative techniques such as scripting, pattern coding, and memoing also took place.

Chapter 7. Evaluation of the SMILE Problem Solving Method

This chapter reports on the research methods, subjects, instruments, and data analysis for validating the SMILE Problem Solving Method supporting educational and training design activities. It addresses the research question “What are the characteristics of the SMILE Method that could predict high performance in solving design problems?” The Method suggests an approach that can improve the educational practice of solving design problems by applying concept mapping. It combines in a systematic way the advantages of different mapping approaches and creative problem solving. The method is aimed at supporting knowledge elicitation, reflection, representation and creation in ill-structured problem solving situations. It could be generalised to a large scope of ill-structured situations and can be applied without using any sort of software. Maps can be drawn as paper and pencil activities. However, it is assumed that when software is used the method would be more efficient. The purpose of this chapter is to evaluate the performance effectiveness of the method in ill-structured problem situations when no computer software is used.

The procedure for verifying the method preceded the idea of designing and developing the SMILE Maker Tool. It subsequently became a substantial part of the SMILE Maker Tool, carrying the name ‘SMILE Method’. Thus, throughout this chapter the method for solving problems in an ill structured design situations is going to be refereed as ‘SMILE Problem Solving Method’. Chapter 5 discussed how the SMILE method was implemented within the structure of the SMILE Maker Tool. Chapter 8 ‘Evaluation of the SMILE Maker Tool’ will give the results of an evaluation the SMILE Method within the SMILE Maker Tool as a problem solving and learning tool.

There are two phases in the evaluation of the SMILE Problem Solving Method: assessment of the conceptual model and an experimental validation of the Method. The conceptual model was checked during two international workshops where expert focus group interviews were carried out. The experiment was conducted with groups of students. One group used the classical concept mapping approach and another group applied the SMILE Problem Solving Method to solve a case. A set of maps drawn by hand evidenced the process of solving the case. In addition to the main effect, a possible interaction effect between method and learning styles was tested.

Section 7.1 presents details about the subjects, instruments, procedure, results and discussion of the findings after the evaluation of the SMILE Problem Solving Method conceptual model.

Section 7.2 describes the experimental design, subjects, instruments, procedures, and the results of the experiment aimed at validating the SMILE Problem Solving Method.

7.1 Evaluation of the conceptual model of the SMILE Problem Solving Method

The conceptual model of the SMILE Problem Solving Method was evaluated during two international workshops. The first was organised during the of Ed-Media Conference in Freiburg (Germany) in June 1998 (Kommers & Stoyanov, 1998) and the second one was part of the conference 'Information Society Technologies' in Sofia (Bulgaria) in July the same year. The purpose of these workshops from the perspective of the SMILE Method evaluation was to get some information about the attitudes toward the structure, procedures, and possible implementation of the method when confronted by panels of experts.

7.1.1 The workshop in Freiburg (Germany), 1998

This workshop was a pre-conference event of the Ed-Media'98 Conference. According to the rule of the conference the participants who were willing to take part in the event had to pay in advance a fee in order to register for the workshop.

7.1.1.1 Subjects

The workshop in Freiburg attracted the attention of 18 participants, mostly academicians from Australia, China, Germany, Israel, Sweden, United Kingdom and USA. They expected to get information about the classical concept mapping approach in the domain of education and how to use mental mapping software such as 'Inspiration' and 'Mind Man' (The previous version of the Mind Manager). The participants also showed an interest to know not only about concept mapping as a graphical advance organiser and test substitute, but also about the role of concept mapping in the process of solving design problems.

7.1.1.2 Procedure

The workshop was divided into two parts: concept mapping – definitions, theoretical framework, functions, examples and software; and the SMILE Problem Solving Method – rationale, procedure, and practice. There was a Power Point presentation of the SMILE Problem Solving Method and after that a formal and informal discussion about the method took place. A short session of practicing the method was organized at the end of the workshop. The participants selected an artificial problem and applied the procedure of the Method only for the first stage of the Method – map information collection. Facilitators captured and mapped the ideas of participants using the 'Inspiration' software.

7.1.1.3 Instruments and data analysis

A semi-structured interview questionnaire to give the general lines of discussion was prepared in advanced (see Appendix 15). The interview consisted of five questions concerning the idea of combining different mapping approaches and problem solving techniques, the phases of the process, reaction to some particular techniques, types of the links and labels, and eventual benefits for the educational and training practice.

Because of some technical difficulties the discussion with experts was not recorded. The data were collected by note taking during the interview and analysed later searching across for some patterns. A memo describing the purpose, procedure and the main results from the discussion was written afterwards.

7.1.1.4 Results

Based on the presentation and the experience in applying the method the participants in the workshop expressed their positive attitudes towards the method as general and more specifically to the ideas such as:

- Combining the advantages of mapping and problem solving
- The stages of the method with the special emphasis on looping between stages.
- Capturing either cognitive or affective problem solving representations such as facts, statistics, opinions, metaphors and hedonistic feelings.
- Using different labels on the links to represents the variety of complex relationships in a problem situation – descriptive, structural, causal, interrogative, and metaphorical.
- Using some creative techniques within each stage.

However some of the participants admitted that it was difficult for them at the beginning to understand what the method was about. They said the method is complicated and some more explicit explanation, examples and practice were needed. In addition they expressed their concerns about the application of the method in an educational setting.

7.1.2 Workshop in Sofia (Bulgaria), 1998

The workshop in Sofia (Bulgaria) was scheduled during the conference ‘Information Society Technologies’. The workshop was organised in response to an invitation from the organisation committee of the conference. The workshop had the same structure as the previous workshop in Freiburg although it did not enjoy the success that was perceived by the facilitators in comparison to the first workshop.

7.1.2.1 Subjects

The audience taking part in this workshop included 12 academicians from some universities in Bulgaria, Hungary and Netherlands. In addition, 15 students, mainly from the Faculty of Mathematics and Informatics at Sofia University, were invited as well.

7.1.2.2 Procedure

The procedure was the same as that at the workshop in Freiburg. The first part of the workshop included a Power Point presentation about what is concept mapping, the theoretical framework behind the technique, guidelines for how to make a concept map and the most popular concept mapping software. The second part of the workshop introduced SMILE Method again by a Power Point presentation. A practical session was planned as well. The participants had to apply the SMILE Method to a problem related to the main theme of the conference.

7.1.2.3 Instruments and data analysis

A semi-structured interview questionnaire was prepared in order to frame the reflections of the participants about the SMILE Method. A tape recorder was ready to capture the discussion. However, the discussion did not go in the expected direction and did not contribute very much to getting feedback about the conceptual blueprint of the SMILE Method. The students were very passive while one of the participants (one of the invited speakers of the conference) dominated the discussion. He was a person with a strong inclination for philosophical debates. The idea for practicing the Method failed because the participants were not willing to do so. They preferred to keep discussing the theoretical issues around the SMILE Method as they saw them.

However, while this discussion did not bring operational suggestions for the SMILE Method, it prompted the need of explaining why concept mapping and mental mapping in general are essential for the SMILE Problem Solving Method; what makes mapping a strong candidate for the method that support problem solving in ill-structured situation; how mapping contributes to this method; and what the theoretical background is which mapping is based upon. In addition there was considerable enthusiasm in defending heuristics as the single best approach for problem solving. While such generalisations condemn the flexibility and multiple perspectives looking at the issue, the idea of heuristics was taken into account and applied in the SMILE Problem Solving Method. The procedures of creating the map information collection, map idea generation, map idea selection and map idea implementation could be described as a sort of heuristics. What happened during the seminar in Sofia was related to one of the descriptors of the concept of triangulation. That is to find by purpose or accident a person or a group that apparently will question the conceptual framework of the method (Patton, 1990; Miles & Huberman, 1999). Certainly the workshop in Sofia was not deliberately looking for such a case, but by its consequences it played such a role. This workshop could be described as a negative case in the terms of qualitative research paradigm (Patton, 1990). Chapter 6 'The Methodology for the SMILE Maker evaluation' refereed to this issue.

7.1.3 Conclusions about the conceptual model of the SMILE Problem Solving Method

The basic idea of the evaluation of the conceptual model of the SMILE Problem Solving Method during the two workshops was to get some feedback from experts in a relatively open research environment. The participants were encouraged to reflect on and discuss their experiences when using the Method when solving a case.

The SMILE Method received a good acceptance during the first workshop in Freiburg as some assumptions about the method were confirmed. The participants expressed their positive attitudes to the following ideas:

- The basic idea of consolidating mapping approaches and problem solving.
- The idea of involving not only concept mapping but also other mapping approaches.
- The process of problem solving as consisting of stages with particular objectives.
- The need for supporting the problem solving activities with relevant creative problem solving techniques.
- The idea of using canonical and idiosyncratic labels (descriptive, structural, causal, interrogative, and metaphorical) on the links to represent the structure of a complex problem solving situation.
- The idea of describing the perception of an ill-structured problem situation through either cognitive or affective types of knowledge items (facts, statistics, opinion, feelings, and metaphors).
- High interest in mapping software, especially 'Inspiration'.

Apart from that, some suggestions were made as well. There was a recommendation for adding a problem definition as a stage of the method. The idea of looping against linearity of stages was also put into consideration. Based on experience with some mapping software, the participants expected more explicit support for how, when and where to use mapping techniques, not only how to apply their graphical editors.

The second workshop brought in also some interesting ideas:

- Information about the theoretical background and mechanisms behind the method is needed.
- Applying the idea of heuristics.
- The method should be enough flexible for different approaches, incorporating the vision and even the preoccupations of the users.

During the two workshops some qualitative data were collected to validate the conceptual model of SMILE method. The next step was to validate the method in more controlled experimental conditions in order to get some more generalisable findings. The quantitative validation of the SMILE Method is the purpose of the following section.

7.2 Experimental validation of the SMILE Problem Solving Method

This section provides information related to the experimental design, subjects, instruments, procedures, data analysis and discussion of the data collected to validate the SMILE problem solving method. The experiment should give some indications whether the SMILE method is more effective than the traditional concept mapping approach for solving design problems. The expectations are based on the explicit systematic support that the SMILE method provides for knowledge elicitation, reflection, representation and creation during information collection, idea generation, ideas selection and idea implementation. The experiment was conducted in October 1998.

7.2.1 Experimental design

A factorial experimental design (2x2) with a post-test-only control group was chosen as the most relevant to meet the purpose of this type of evaluation in this context. The independent variables are the two level problem solving mapping method (the SMILE mapping method and the traditional concept mapping method) and the two level learning style (Doers and Thinkers). It was assumed that learning styles might influence the main effect of the experiment as the results of some research had indicated. Oughton and Reed (2000) reported on the effect of learning styles on some characteristics of map production (See Section 3.2.2 for more details). Learning styles were selected as representatives of the individual differences among people. They are integrative multi-level personal constructs including some elements of the ability, cognitive styles and personal traits.

The dependent variable of the current experiment was the concept mapping production scored on a Scheme including several criteria, which will be discussed in Section 7.2.4.2.

This experimental design was selected because a random assignment to the conditions was possible at a certain stage. The combination of random assignment and the establishment of a control group served to eliminate the majority of threats to both the external and internal validity of the study. Although the proportion of dropouts was reported as a potential threat to internal validity not controlled for this type of design, it did not prove to be a problem in our case. The research was conducted in a one-day session and the size of groups remained constant throughout the duration of the study.

7.2.2 Hypotheses

Two hypotheses are formulated in this research. The first was about the main effect of the independent variables on the dependent variable. The second hypothesis is to test whether an interaction effect exists between the two independent variables in relation to the dependent variable.

7.2.2.1 Hypothesis 1

The subjects in the experimental group using the SMILE Method will score higher than the subjects in the control group applying a classical concept mapping method for problem solving on the characteristics of map production.

7.2.2.2 Hypothesis 2

Individual differences in learning styles will affect the effect of the 'Method' variable on 'map production'. The method has a differential effect on mapping production because of varieties in the learning preferences.

7.2.3 Subjects

The sample for this study was selected from a total of 52 fourth- year students studying in the Faculty of Mathematics and Informatics of Sofia University (Bulgaria). Thirty-two students were randomly selected and then equally assigned to the experimental and the control group according to their learning styles. Section 7.2.5 provides details about how this was done.

7.2.4 Instruments

Two research instruments were applied for measuring the effects of independent variables on dependent variables. These are the Learning Style questionnaire (Honey & Mumford, 1992) (Section 7.2.4.1) and a mapping production scoring scheme (Section 7.2.4.2).

7.2.4.1 Learning style questionnaire

The Learning Style Questionnaire of Honey and Mumford (1992) was used as one of the measuring instruments in this study. It consists of eighty items to identify four learning styles: Activist, Reflector, Theorist, and Pragmatist. The Test-Retest reliability of the questionnaire is reported to be high .89. In order to simplify the experimental design and to ensure an equal representation of the learning styles, the four learning styles were merged into two groups - thinkers (Theorists and Reflectors) and doers (Activists and Pragmatists). Honey and Mumford (1992) suggested a possibility for reducing, if necessary, the four styles to two for the purposes of a research. Traditionally, most of the classifications of cognitive and learning styles use a dichotomy: field dependent - field independent, holist - serialist, convergent - divergent.

7.2.4.2 Mapping production scoring scheme

The scoring scheme for mapping production was based upon the four criteria: *broad perception, divergency, convergency, and planning*. The choice of the four criteria was based upon the structure of the problem solving process: analysis of the problem situation, generation of ideas, selection of an idea, and solution implementation. A problem solving process begins with collection of information, an exploration of the problem situation and problem re-definition if necessary (broad perception). The broader the perception of the problem situation, the higher is the probability of considering all factors that might contribute to proposing relevant solutions. Based on this broad view the next task in problem solving is the generation of alternative solutions, as many as possible (divergency). After idea generation, the objective of the next step is the selection of the most appropriate candidate(s) among ideas (convergency). Finally the chosen solution should be put into practice which is related to planning criteria.

- The criterion of ‘Broad Perception’ expresses the extent to which a problem solver represents comprehensively the problem situation under study. This criterion could be operationalised by some indicators such as:
  - Fluency - number of nodes; number of links;
  - Flexibility - variety of nodes: facts, data, personal experience, opinions, feelings, hypothesis, metaphors & analogies; variety of labels: descriptive, structural, causal, interrogative, remote associations; variety of links: one-directional, bi-directional, cross-links.
- ‘Divergency’ is defined as the extent to which a problem solver produces alternative solutions. The indicators, which describe this criterion, are:

  - Fluency - number of ideas;
  - Flexibility - variety of ideas: ready-made solutions, elaboration, suggestions, and unusual ideas.

- 'Convergency' is the extent to which a problem solver selects the most relevant solution based on a set of criteria. The set of criteria is defined by the following indicators:
  - Inverse fluency - reducing to one best idea, reducing to a few ideas arranged in consequence, reducing to a few ideas arranged by importance, reducing to a few ideas not arranged, no idea selected at all.

- 'Planning' refers to the extent to which a problem solver lists all factors that could affect the implementation of a solution, assigns a set of preventive actions against the negative ones and presents the solution in the terms of sequence of activities and events.
  - The availability of a plan for action is an indicator for 'planning'.

This scoring scheme is based on the approach of Novak (1984, 1998) in scoring concept maps and the criteria for creative thinking developed by Guilford (1967). It also takes into account the specific purposes and functions of the SMILE Method. The reliability of the coding of mapping production was checked as well. Firstly two independent evaluators coded six maps each (three from the experimental group and three from the control group) and compared the results of their scoring. The intercoder reliability is a relation between the number of agreements and the total number of agreements and disagreements (Miles & Huberman, 1994). Based on this formula the intercoder reliability initially had the value of 75 %. Because this is assumed as not a very high reliability, the two evaluators discussed the value of each of the indicators and arrived at a consensus. As a result the intercoder reliability reached the value of 85 %. An example of a coded map is presented in Appendix 16.

7.2.5 Procedure

The learning style questionnaire was distributed among the subjects to be filled in. Based on the results, the students were proportionally assigned to the control and the experimental groups in order for both learning styles (thinkers and doers) to be equally represented.

The students in the control group were introduced to classical concept mapping and mind mapping methods and they were asked to select one of the techniques or combine some of its components. As a result all of the students chose the classical concept mapping method with some characteristics of mind mapping. This kind of concept map is known as a spider map. Buzan (1996) claimed that a spider map is not a kind of mind map as people may think. The control group got some training in concept mapping.

The experimental group was introduced to the SMILE Method. Because of lack of time the experimental group was not able to receive the amount of training in the new Method as was planned. The students were introduced to the procedure of applying the Method in a problem solving situation but they did not get opportunities to practice.

A case to be solved was presented to the students in both the control and the experimental group and they were asked to use the methods they had been introduced to solve a case. The case, called the ‘George’s Career Dilemma’ (See Appendix 17) represents a situation in which a last year student is confronted with a problem to take the most appropriate solution about his future.

As a reinforcement mechanism bringing more motivation to the students to participate seriously in the experiment, several demo versions of mapping software tools were installed for free to be used after the experiment.

7.2.6 Data Analysis

Two-way analysis of variance (ANOVA) was chosen as an appropriate statistical procedure for the factorial experimental design applied in the current study. ANOVA has proved to be robust to the violations of the basic assumptions to apply a parametric statistical procedure. That means that the level of significance is little affected by a violation of one or more of these assumptions. The probability of data analysis was established at an alpha level of .05. The SPSS 8.0 package was used for the analysis of the data.

7.2.7 Results

This section presents the results from data analysis after ANOVA. They are grouped under headings based upon the set of criteria determining the scoring scheme of mapping production. The raw data and descriptive statistics are presented in Appendix 18.

7.2.7.1 Broad perception - nodes

The experimental group proved to be significantly better than the control group on the indicator ‘fluency of nodes’ of the broad perception criteria – $F (1, 28)=6.297$, $p=.018$. The subjects in the experimental group produce considerably more information items than subjects in the control group. The experimental group also demonstrates significantly higher results on the ‘flexibility of nodes’ – $F (1, 28)=55.446$, $p=.0001$ (See Table 5 and Figure 25).

Table 5. Broad perception - nodes

Dependent Variable	Method	Mean	Std. Deviation	N
Fluency – Number of nodes	Traditional	10.6875	3.5160	16
	SMILE	16.7500	8.7977	16
	Total	13.7187	7.2745	32
Flexibility – Variety of nodes	Traditional	2.1875	.4031	16
	SMILE	4.6875	1.2500	16
	Total	3.4375	1.5645	32
Relative number of **Facts**	Traditional	71.9375	7.6111	16
	SMILE	48.5000	10.2827	16
	Total	60.2188	14.8644	32
Relative number of **Opinions**	Traditional	27.9375	7.6111	16
	SMILE	13.9375	10.5734	16
	Total	20.9375	11.5198	32
Relative number of **Data**	Traditional	.0000	.0000	16
	SMILE	7.9375	9.0515	16
	Total	3.9688	7.4768	32
Relative number of **Personal Experience**	Traditional	.0000	.0000	16
	SMILE	7.6250	9.0985	16
	Total	3.8125	7.4203	32
Relative number of **Feelings**	Traditional	.5675	2.2488	16
	SMILE	14.6250	7.2007	16
	Total	7.5963	8.8619	32
Relative number of **Hypotheses**	Traditional	.0000	.0000	16
	SMILE	5.5625	6.5317	16
	Total	2.7813	5.3505	32
Relative number of **Metaphors & Analogies**	Traditional	.3125	1.2500	16
	SMILE	4.1875	5.2436	16
	Total	2.2500	4.2350	32

Dependent Variables	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Fluency -Number of Nodes	METHOD	294.031	1	294.031	6.297	.018*
	L Style	.781	1	.781	.017	.898
	METHOD * L Style	38.281	1	38.281	.820	.373
Flexibility – Variety of Nodes	METHOD	50.000	1	50.000	55.446	.000*
	L Style	.500	1	.500	.554	.463
	METHOD * L Style	.125	1	.125	.139	.712
Facts - Relative number	METHOD	4394.531	1	4394.531	50.948	.000**
	L Style	38.281	1	38.281	.444	.511
	METHOD * L Style	1.531	1	1.531	.018	.895
Opinions - Relative number	METHOD	1568.000	1	1568.000	17.372	.000**
	L Style	12.500	1	12.500	.138	.713
	METHOD * L Style	6.125	1	6.125	.068	.796
Data - Relative number	METHOD	504.031	1	504.031	12.802	.001*
	L Style	63.281	1	63.281	1.607	.215
	METHOD * L Style	63.281	1	63.281	1.607	.215
Personal Experience - Relative number	METHOD	465.125	1	465.125	11.510	.002*
	L Style	55.125	1	55.125	1.364	.253
	METHOD * L Style	55.125	1	55.125	1.364	.253
Feelings - Relative number	METHOD	1580.906	1	1580.906	62.837	.000*
	L Style	101.816	1	101.816	4.047	.054***
	METHOD * L Style	47.336	1	47.336	1.881	.181
Hypotheses - Relative number	METHOD	247.531	1	247.531	13.810	.001*
	L Style	69.031	1	69.031	3.851	.060****
	METHOD * L Style	69.031	1	69.031	3.851	.060
Metaphors & Analogies - Relative number	METHOD	120.125	1	120.125	8.269	.008*
	L Style	21.125	1	21.125	1.454	.238
	METHOD * L Style	8.000	1	8.000	.551	.464

* (In favour of the SMILE method) *** (In favour of Doers)
** (In favour of the Classical concept mapping method) **** (In favour of Thinkers)

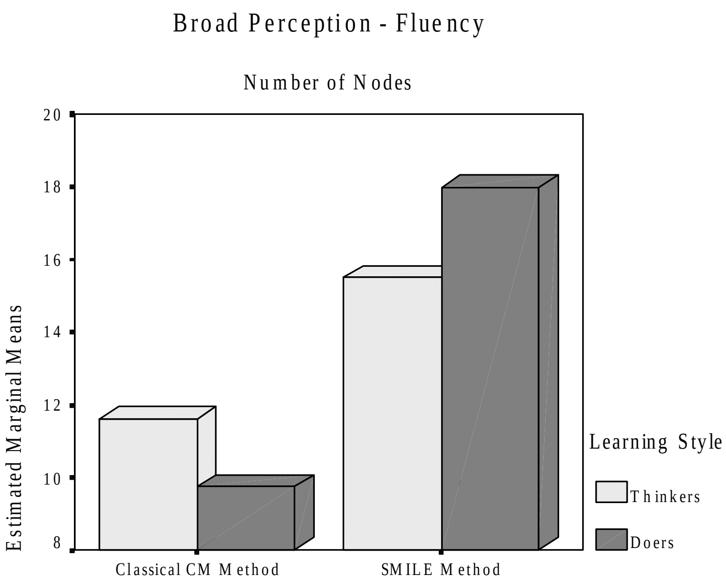


Figure 25. Broad perception - fluency of nodes

The distribution of the different types of nodes in total shows that the students in the experimental group include relatively much more statistical data and figures - F (1, 28)=12.802, p=000, personal experience - F (1, 28)=11.510, p=.002, hypotheses - F (1, 28)=13.810, p=.001, feelings - F (1, 28)= 62.837, p=.000, and metaphors and analogies - F (1, 28)=8.269, p=.008, than students in the control group. No one of the maps in the control group contains the following types of nodes: statistical data and figures, personal experience, and hypotheses. The perception of the problem space in the control group is dominated mostly by facts - F (1, 28)=50.948, p=.000 and opinions - F (1, 28)=17.372, p=.000. (See Table 5 and Figure 26)

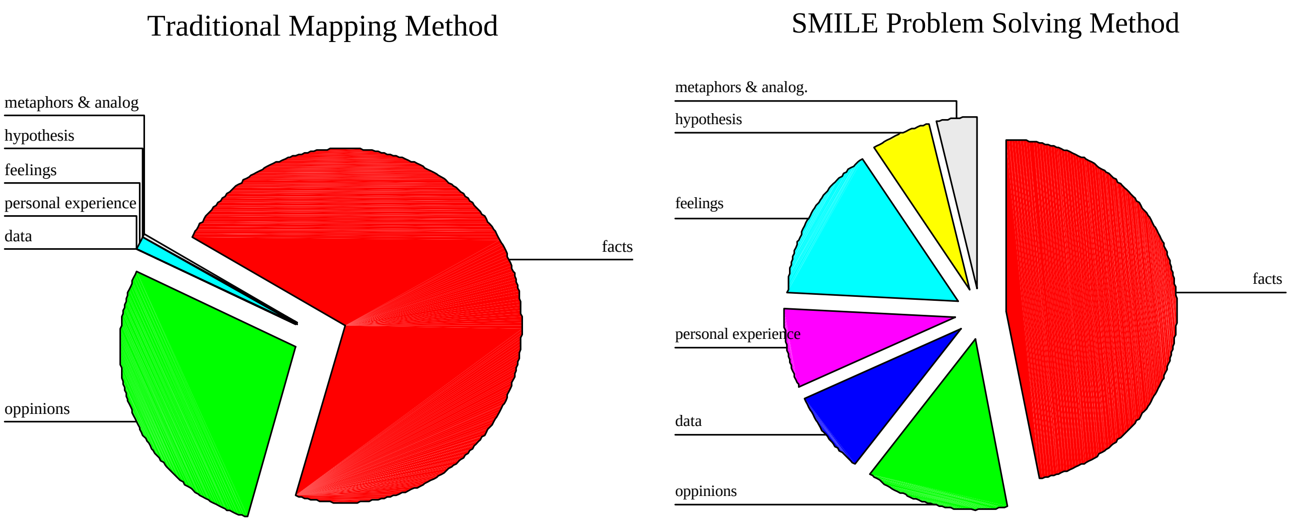


Figure 26. Broad perception - distribution of nodes

The data show that the SMILE problem solving method stimulates students in the experimental group to express the complexity of their problem solving representations more than the students applying classical concept mapping method. Students in the experimental group use not only facts but also feelings, metaphors and analogies, and assumptions.

7.2.7.2 Broad perception - links

There was not a significant difference on the indicator 'fluency of links'. As the students in the experimental group produced more nodes the students in the control group use relatively more links per node (See Table 6 and Figure 27).

Table 6. Broad perception – links

Dependent Variable	Method	Mean	Std. Deviation	N
Fluency – Number of Links	Traditional	17.7500	5.6510	16
	SMILE	17.8750	9.7014	16
	Total	17.8125	7.8100	32
Flexibility – Variety of Links	Traditional	2.4375	.6292	16
	SMILE	1.6250	.8062	16
	Total	2.0313	.8224	32
Relative number of **One-directional Links**	Traditional	76.4375	15.7986	16
	SMILE	95.1875	8.7576	16
	Total	85.8125	15.7673	32
Relative number of **Bi-directional Links**	Traditional	12.8125	12.6503	16
	SMILE	2.1875	5.0096	16
	Total	7.5000	10.8954	32
Relative number of **Cross-Links**	Traditional	10.1875	8.2075	16
	SMILE	4.5625	7.0330	16
	Total	7.3750	8.0432	32

Dependent Variables	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Fluency -Number of Links	METHOD	.125	1	.125	.002	.965
	L Style	40.500	1	40.500	.653	.426
	METHOD * L Style	112.500	1	112.500	1.813	.189
Flexibility – Variety of Links	METHOD	5.281	1	5.281	10.469	.003**
	L Style	3.125	1	3.125	.062	.805
	METHOD * L Style	1.531	1	1.531	3.035	.092
One-directional Links-Relative number	METHOD	2812.500	1	2812.500	16.490	.000*
	L Style	40.500	1	40.500	.237	.630
	METHOD * L Style	78.125	1	78.125	.458	.504
Bi-directional Links - Relative number	METHOD	903.125	1	903.125	9.965	.004**
	L Style	231.125	1	231.125	2.550	.122
	METHOD * L Style	8.000	1	8.000	.088	.769
Cross-Links - Relative number	METHOD	253.125	1	253.125	5.029	.033**
	L Style	55.125	1	55.125	1.095	.304
	METHOD * L Style	288.000	1	288.000	5.722	.024

* (In favour of the SMILE Method)

** (In favour of the Classical concept mapping method)

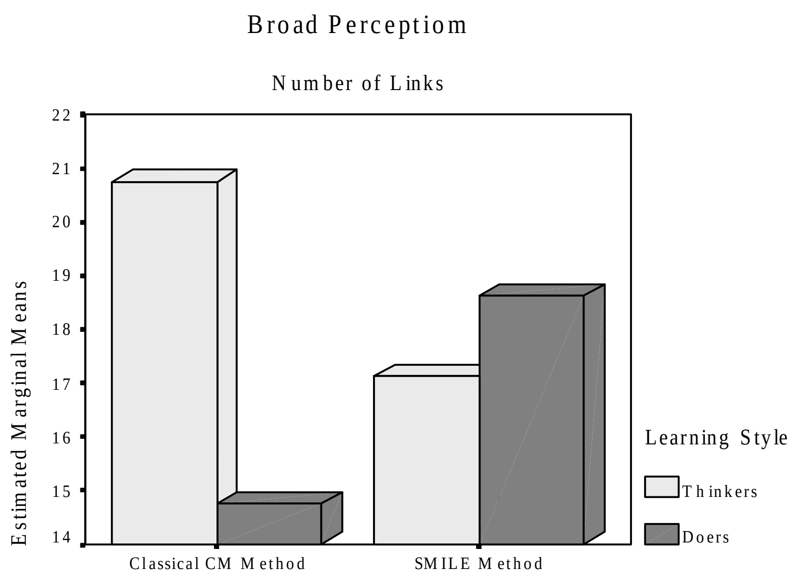


Figure 27. Broad perception -fluency of links

The subjects working with the classical concept mapping method scored significantly higher than their fellows in the experimental group on the relative number of bi-directional - F (1, 28)= 9.965, p=.004, and cross-links - F (1, 28)= 5.029, p=.033. The subjects in the experimental group use mostly one-directional links - F (1, 28)=16.490, p=.000. (See Table 6 and Figure 28)

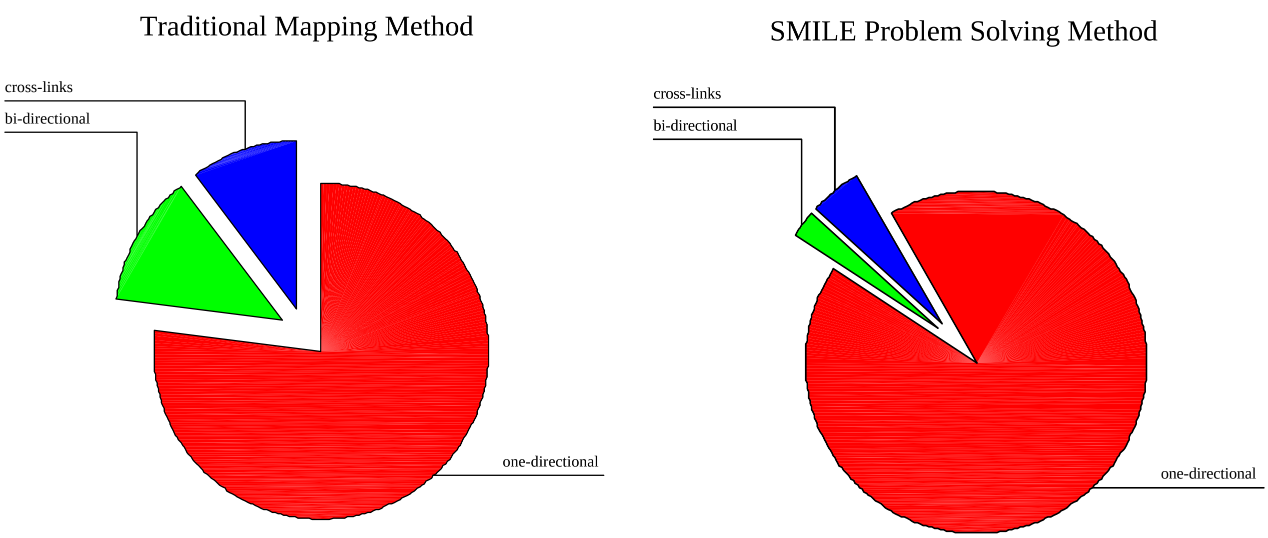


Figure 28. Broad perception - distribution of links

A possible explanation might be that subjects using the classical method were forced to use the whole repertoire of possible links because they had to represent everything on one sheet of paper. The subjects in the experimental group had more room to manoeuvre with four maps to be drawn. This particular feature of the new method gives the subjects in the experimental group more memory space, mapped into different sections - information collection, idea generation, idea selection, and idea implementation. While the traditional method puts all the problem-solving activities in one picture, the new method creates a picture of the whole problem solving process, sharing the cognitive load between the problem solving stages.

7.2.7.3 Broad perception - labels

While the simplicity of the types of links frees up the memory processes, the complexity of the labels' structure provides a deeper perception of the problem solving space. The variety of link labels - F (1, 28)= 5.645, p=.025, is greater in the experimental conditions. The classical concept mapping group used predominantly descriptive types of links' labels - F (1, 28)= 12.948, p=.001. They did not use at all remote association labels. The SMILE Method group used more structural - F (1, 28)= 8.483, p=.007, causal - F (1, 28)= 6.192, p=.019, interrogative - F (1, 28)= 5.358, p=.028, and remote associative - F (1, 28) = 13.064, p=.001, links. (See the Table 7 and Figure 29). The new method uses a more complex verbal code combined with a more simple link structure. It provides a deeper perception of the problem space while reducing the cognitive overload.

Table 7. Variety of labels

Dependent Variable	METHOD	Mean	Std. Deviation	N
Flexibility – Variety of Labels	Traditional	2.7500	.5774	16
	SMILE	3.3750	.8851	16
	Total	3.0625	.8007	32
Relative number of **Descriptive** Labels	Traditional	53.3125	24.3741	16
	SMILE	25.9375	16.5508	16
	Total	39.6250	24.7670	32
Relative number of **Structural** Labels	Traditional	7.0000	7.0522	16
	SMILE	14.1875	7.7564	16
	Total	10.5938	8.1552	32
Relative number of **Causal** Labels	Traditional	4.5000	3.5590	16
	SMILE	7.6250	3.6125	16
	Total	6.0625	3.8683	32
Relative number of **Interrogative** Labels	Traditional	.3750	1.5000	16
	SMILE	2.8125	3.8681	16
	Total	1.5938	3.1404	32
Relative number of **Remote Association** Labels	Traditional	.0000	.0000	16
	SMILE	4.8750	5.2520	16
	Total	2.4375	4.4136	32

Dependent Variables	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Flexibility - Variety of Labels	METHOD	3.125	1	3.125	5.645	.025*
	L Style	1.125	1	1.125	2.032	.165
	METHOD * L Style	.125	1	.125	.226	.638
Descriptive Labels - Relative number	METHOD	5995.125	1	5995.125	12.948	.001**
	L Style	6.125	1	6.125	.013	.909
	METHOD * L Style	50.000	1	50.000	.108	.745
Structural labels - Relative number	METHOD	413.281	1	413.281	8.483	.007*
	L Style	215.281	1	215.281	4.419	.045***
	METHOD * L Style	69.031	1	69.031	1.417	.244

Dependent Variables	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Causal Labels - Relative number	METHOD	78.125	1	78.125	6.192	.019*
	L Style	.500	1	.500	.040	.844
	METHOD * L Style	32.000	1	32.000	2.536	.122
Interrogative Labels - Relative number	METHOD	47.531	1	47.531	5.358	.028*
	L Style	9.031	1	9.031	1.018	.322
	METHOD * L Style	.781	1	.781	.088	.769
Remote Associations Labels - Relative number	METHOD	190.125	1	190.125	13.064	.001*
	L Style	3.125	1	3.125	.215	.647
	METHOD * L Style	3.125	1	3.125	.215	.647

* (In favour of the SMILE Method)

** (In favour of the Classical concept mapping method)

*** (In favour of Thinkers)

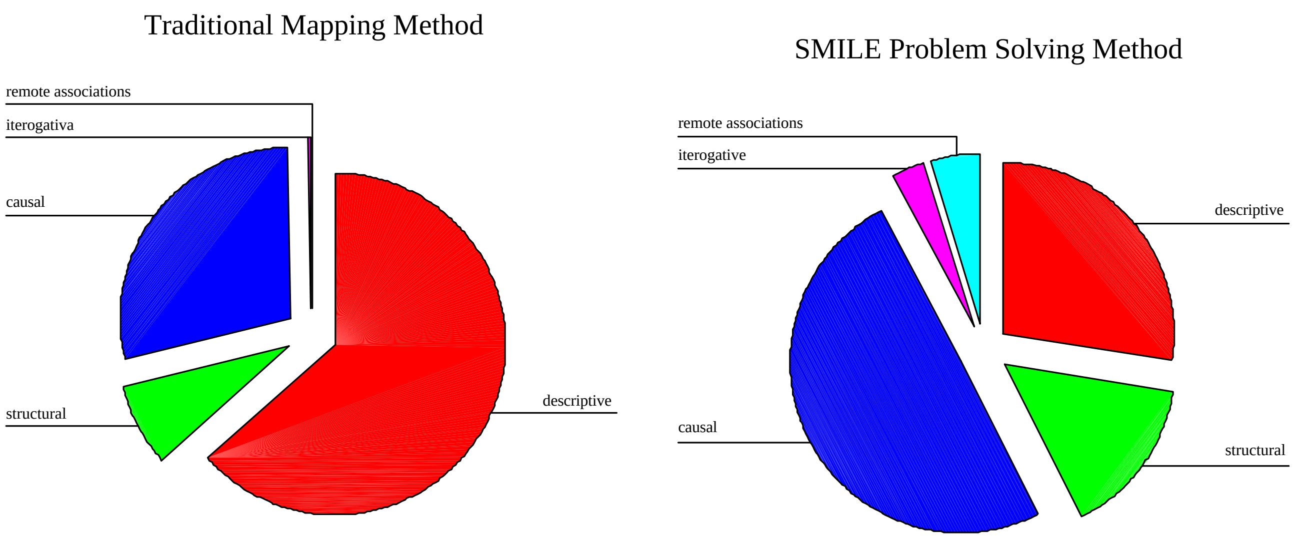


Figure 29. Broad perception -variety of labels

7.2.7.4 Divergency, Convergency, and Planning

The experimental group was superior on the criteria of divergency as the scores on number of ideas ($F(1, 28)= 20.171$, $p=.000$) and the variety of ideas $F(1, 28)= 9.031$, $p=.006$) are significantly higher than the same indicators of the control group. The subjects in the experimental group were significantly better on the convergency criteria when the best candidate among the alternatives should be selected - $F(1, 28)= 9.295$, $p=.005$. The students in the experimental group outperformed the students in the control group on the planning criteria as well - $F(1, 28)= 10.845$, $p=.003$ (See the Table 8).

Table 8. Divergency, Convergency and Planning

Dependent Variable	Method	Mean	Std. Deviation	N
Divergency – number of ideas	Traditional	3.3125	1.4477	16
	SMILE	12.5000	8.5713	16
	Total	7.9063	7.6384	32
Divergency – variety of ideas	Traditional	1.1250	.3416	16
	SMILE	1.9375	.9979	16
	Total	1.5312	.8418	32

Dependent Variable	Method	Mean	Std. Deviation	N
Convergency	Traditional	1.2500	.9309	16
	SMILE	2.3750	1.2583	16
	Total	1.8125	1.2297	32
Planning	Traditional	.6875	.6021	16
	SMILE	1.8750	1.3601	16
	Total	1.2813	1.1977	32

Dependent Variables	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Divergency – number of ideas	METHOD	675.281	1	675.281	20.171	.000*
	L Style	94.531	1	94.531	2.824	.104
	METHOD * L Style	101.531	1	101.531	3.033	.093
Divergency – variety of ideas	METHOD	5.281	1	5.281	9.031	.006*
	L Style	.281	1	.281	.481	.494
	METHOD * L Style	3.125	1	3.125	.053	.819
Convergency	METHOD	10.125	1	10.125	9.295	.005*
	L Style	3.125	1	3.125	2.869	.101
	METHOD * L Style	3.125	1	3.125	2.869	.101
Planning	METHOD	11.281	1	11.281	10.845	.003*
	L Style	1.531	1	1.531	1.472	.235
	METHOD * L Style	2.531	1	2.531	2.433	.130

* (In favour of SMILE Method)

7.2.7.5 Learning styles

The analysis of the style variable shows that Thinkers expressed significantly more structural types of links than the Doers – F (1,28)= 4.419, p=.045 (Table 7). They also formulated substantially more assumptions items than doers. The result is quite close to being a significant difference at the 0.5 level of probability – F (1,28)= 3.851, p=.060 (See Table 5 and Appendix 19). Thinkers naturally tend to present the information into classifications and clusters. They also tend to generate more hypotheses. A good prerequisite for this is a well-established structure. Doers express more feelings in the perception of the problem solving space – F (1,28)= 4.047, p=.054 (See Table 5 and Appendix 19). This is probably because they are more extravert-oriented people.

With the new method the Thinkers reduced considerably the number of cross-links – F (3,26)= 5.722, p=.024 (See Table 6 and Appendix 19). Thinkers applying the classical concept mapping approach need more cross-links to express the structural complexity of the problem solving space. The new method gives them opportunities to distribute the structural complexity among several maps.

7.2.7.6 Interaction effect

The data show no interaction effect between the two independent variables of method and style on the dependent variable of map production. The SMILE Method proved to have a general beneficial effect across all learning styles. However there was not so much learning during this experiment or at least the learning did not affect very much the results. The administration of the experiment had a side effect outside the experimental conditions. People were very willing to fill in the learning style questionnaire. We had students not taking part in the experiment who wanted to fill in the questionnaire. It was defined as a positive indication for including Honey and Mumford's (1992) learning styles questionnaire as a part of the learning environment of the SMILE Maker Tool. The issues presented by learning styles in this experiment brought attention to the role of learning for studying and applying a concept mapping method. The learning environment of the SMILE Maker Tool is an attempt to deal with this matter.

7.2.8 Discussion

The experimental results support the hypothesis that the SMILE Method is significantly better than the traditional concept mapping approach in a situation of problem solving. Certainly the point is not so much whether the SMILE Method is better but rather how and why it is a better method for solving design problems. The new method proved to be more effective in information collection, but especially in idea generation, idea selection and idea implementation activities. It enables broaden perception with more and diverse information items and more complex labels on the links. Broad perception is a good predictor for the number and the originality of ideas. The new method supports the evaluation of ideas and the selection of the most appropriate one to be implemented into practice.

The SMILE Method promotes a broader and more complex cognitive structure than traditional approaches with a dominance of the structural, interrogative, causal and remote associative types of links over the more simple descriptive types of links which are more frequent in the classical concept mapping approach.

The new concept mapping method gives more space for scanning not only cognitive but also affective problem solving representations. The psychological distance between types of information items on the scale of objectivity-subjectivity is larger in the experimental group. For example, data are very objective and feelings are very subjective. This is a prerequisite for breaking the fixedness of existing patterns and stimulates creative combinations in the idea generation phase.

Subjects in the experimental group knew that they would start with the map information collection and would end up with the map implementation. The externalisation of cognitive and affective structures by a sequence of maps involves much perception. Perception itself takes over some of the mental tasks during problem solving thus contributing to reducing the memory overload. It makes the reasoning processes more easy and flexible. While the traditional method draws one picture trying to include all problem solving activities, the new method creates the picture of the whole problem solving process distributing the cognitive load between the problem solving stages. The new method brings a perspective and a direction to the activities - from broad perception to planning. It is a cognitive aid for guiding and planning through the stages of problem solving. The SMILE Method supports not only reflection-*on* a particular map production (information collection, idea generation, idea selection, and idea implementation), but also reflection-*in* the process of accomplishing design tasks. Thus the new method stimulates self-appraisal, self-monitoring, and self-management.

The data support the expectation that the SMILE Method brings a general beneficial effect regardless of different learning styles. It establishes a body of skills in all problem-solving activities - information collection, idea generation, idea selection, and idea implementation. Thus the method has the potential to develop comprehensive versatile styles rather than one-side preference.

The data revealed a cognitive construct explaining why the SMILE Method produced better results than the classical concept mapping approach. The construct has four characteristics: knowledge elicitation, knowledge reflection, knowledge representation and knowledge creation. While the phases of the SMILE Method represent a valuable framework for posting problem solving activities, knowledge elicitation, knowledge reflection, knowledge representation and knowledge creation constitute the operational mechanism for this framework. In a general sense, the number of nodes, links (broad perception), ideas (divergency), criteria (convergency), negative and positive factors (planning) are some of the indicators of knowledge elicitation. The variety of nodes, links (broad perception), ideas (divergency), criteria (convergency), factors (planning) are operationalisations of the knowledge representation. Knowledge reflection could be expressed by the extent to which clusters and patterns are identified. Knowledge creation implies the number of original solutions that have been generated (divergency). A more conceptual explanation about how SMIILE method contributes to knowledge elicitation, knowledge representation, knowledge reflection and knowledge creation follows.

- *Knowledge elicitation*. The SMILE Method offers special techniques for accessing and retrieving deep cognitive and affective structures during information collection to broaden the perception of the problem space. In the idea generation phase the SMILE Problem Solving Method stimulates production of as many as possible alternative solutions. The techniques it applies are combinations between some problem solving techniques and the specific characteristics of mental mapping. SMILE Method supports building a set of criteria for choosing the most appropriate solution in the idea selection phase. The method also facilitates the accounting of all factors important for the implementation of the solution. The techniques the SMILE method proposes eliminate some negative problem solving syndromes such as ‘premature closure’, ‘functional fixedness’, and ‘stereotyping’.

- *Knowledge representation*. The SMILE Method promotes a variety of problem solving representations and a variety of links between them to build a meaningful network when exploring a problem solving space. It stimulates using not only ‘objective’ (facts, statistics) but also ‘subjective’ (feelings, intuitions, assumptions.) knowledge items. The method manages the complexity of a problem solving situation through a set of links of different type: descriptive, structural, causal, and remote associative. Combining verbal and visual coding within a simple graphical format, SMILE maps have a capacity to represent very rich picture of a problem situation. The externalisation of the mental problem solving representations frees up and extends the limited capacity of the working memory thus reducing the cognitive overload when ill-structured cases occur.
- *Knowledge reflection*. The SMILE Method makes explicit the internal problem solving representations in a complex situation. A problem solver is able to reflect on the results and reflect in the process of problem solving. The SMILE Method offers some guidelines and techniques for organizing the problem solving space in a particular way. Mostly it is the case of some convergent activities within each of the phases of the method. For instance, knowledge reflection is supported by the suggestions for reorganizing the problem space, more specifically, clustering some of the items and eliminating others. The visualization of the problem space through mental maps, especially when mapping software is used, helps in manipulation of the knowledge items in a variety of ways. Because of the close correspondence between internal mental structures and the external mode of their representation one could change the way she or he looks at the problem.
- *Knowledge creation*. The opportunity that the SMILE Method provides for a manipulation of nodes in the maps could change dominant thinking patterns and create new ones. The SMILE Method proposes some easy to apply techniques that stimulate creating original and unconventional ideas.

7.3 Summary

This chapter presented the procedure and the results of the evaluation of the SMILE Problem Solving Method. Both qualitative and quantitative strategies were applied for gathering and analysing the data. Some qualitative data were collected in testing the conceptual model of the SMILE Method through expert focus group interviews during two workshops. Some of the ideas about the method that were appreciated by the experts are summarized in the following points:

- Combining the advantages of different mapping approaches and creative problem solving principles and techniques.
- The stages of the method.
- Eliciting of both cognitive and affective problem solving representations.
- Using different labels on the links to represents the variety of complex relationships in a problem situation.

Apart from the positive attitudes of the experts towards the SMILE method, some suggestions were made as well as. Shortly they are as follows:

- Adding problem definition as a separate stage in problem solving process.
- Considering problem solving as a loops-based process instead of a linear one.
- More explicit information about the theoretical background and mechanisms behind the method is needed.
- The idea of heuristics could be applied in the procedure of the method.

An experiment was conducted to get some quantitative data about the effectiveness of the SMILE Method. The map productions of two groups of experimental subjects were compared. The experimental group used the SMILE method while the control group applied a classical concept mapping method. The analysis of the map production showed that the experimental group was significantly better in presenting the comprehensiveness and depth of the problem situation, generation of alternative solutions, selection of the most appropriate one and implementation of the chosen solution. The SMILE Method showed better results because it applied a special means for supporting knowledge elicitation, knowledge representation, knowledge reflection, and knowledge creation.

In addition to the data about the effectiveness of the SMILE Method, the experiment indicated no interaction effect between problem solving method variable and the learning styles variable.

Chapter 8. Evaluation of the SMILE Maker Tool

This chapter reports on the research methods, subjects, procedures, instruments and analysis of the data concerning the evaluation of SMILE Maker Tool. Basically the chapter consists of two major parts. The first one (8.1) discusses the design, subjects, procedure, instruments, and analysis of the results from an experiment aimed at investigating the performance effectiveness of the SMILE Maker Tool as a problem solving and learning tool in ill-structured situations. The second part (8.2) presents the procedures, subjects and the results from experts' focus group interviews of the evaluation of the SMILE Maker Tool. The content of this chapter relates to the following research question: *What is the quantitative and qualitative evidence that the SMILE Maker Tool is an effective tool for problem solving?* Effectiveness was described as the extent to which:

- The SMILE Maker Tool supports people to successfully solve an ill-structured case.
- Mapping production after applying the method is scored high on the criteria of broad perception, divergency, convergency and planning.
- Users react positively to the method, learning environment and the interface of the tool.

There are two directions in which the experiment discussed in this chapter differentiates from the experiment conducted to validate the Method in Chapter 7. Firstly, the experiment in the current chapter emphases the characteristics of the SMILE Maker Tool as a problem solving and learning tool. The experiment presented in Chapter 7 was aimed at validating the SMILE Problem Solving Method without using any sort of software. Secondly, the experiment in this chapter measures the effects of the SMILE Maker Tool on three dependent variables: solutions of an ill-structured case, mapping production, and users' reflections on using the tool. The experiment in Chapter 7 measures only the mapping production of the subjects. The current chapter presents a summative evaluation of the SMILE Maker Tool as a problem solving and learning tool. It measures the effectiveness of both the SMILE Problem Solving Method and learning method implemented in the tool. The experiment for evaluation of the SMILE Maker Tool was conducted in November 2000.

8.1 Experimental evaluation of the SMILE Maker Tool

This section conceptualises the design of the experiment to evaluate the SMILE Maker. The section defines operationally the main variables of the study. It also formulates the hypotheses of the experiment (Section 8.1.2) and reports on experimental subjects (Section 8.1.3), procedures (Section 8.1.4) and measuring instruments (Section 8.1.5) before going on to analyse the data (Section 8.1.6) and comments on the results (Section 8.1.7).

8.1.1 Experimental design and variables

The independent variable of this experiment is a mapping problem solving tool with two levels: Mind Manager and the SMILE Maker Tool. Both apply a method for problem solving based on mapping which is implemented in a learning environment. The dependent variables are solution of a case, mapping production and user attitudes about the method, learning environment and the interface of the tool. The dependent variables could be operationalised in more concrete terms as follows:

- Score on an expert scale for the successful *solution of an ill-structured case* (problem solving performance - outcomes).
- Score on *mapping production* according to the criteria of broad perception, divergency, convergency, and planning (problem solving performance - process).
- Score on the problem solving *method* scale in the *Reflective Questionnaire* (see Appendix 21) (perceived problem solving performance)
- Score on the *learning environment* scale of the *Reflective Questionnaire* (perceived learning performance)
- Score on the *interface* scale of the Reflective Questionnaire.

Apart from the main effect, the experiment controls whether an additional interaction effect exists. It checks the extent to which individual differences among experimental subjects affect the relationship between the primary independent variable and the dependent variables. Individual differences as a mediator variable have the following characteristics: learning style, problem solving style and learning locus of control. The main objective of the experiment is studying the effect of the independent variable of the ’tool’ supporting problem solving on the dependent variables of ‘performance’ on a case, ‘mapping production’ and ’reflections’ of students. It is expected that the nature of the relationship between the primary independent variable and the dependent variables is altered by the level of a third factor (individual differences). This is the reason the individual differences are included in the experimental design and analysis. In addition this experiment tries to identify intervening variable which may explain how and why the relationships between the independent variables and dependent variables occur (see Figure 30).

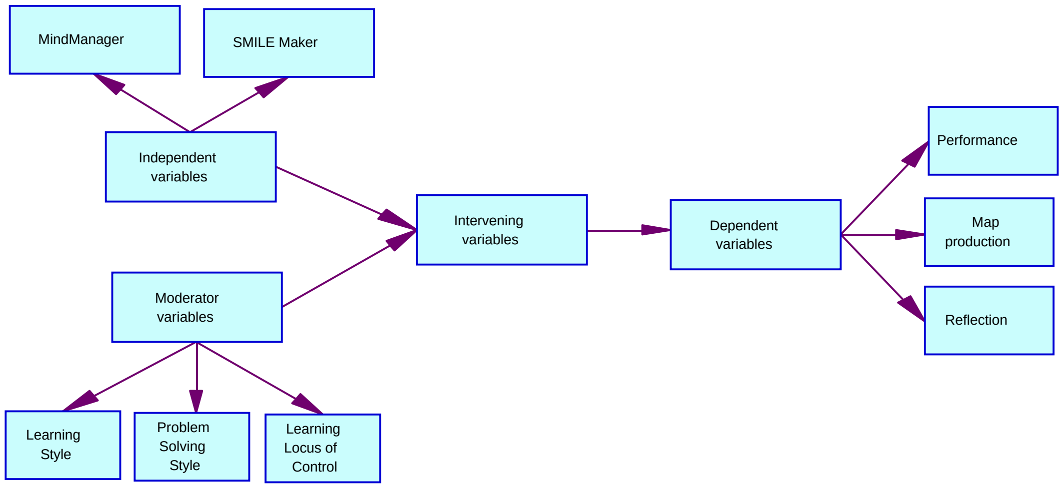


Figure 30. Experimental design of the SMILE Maker Tool evaluation

The experimental design could be defined as 'randomly assigned experimental and control groups with post-test only'. It is described as one of the strongest experimental designs (Krathwohl, 1993). Students are assigned randomly to the control and the experimental group. The control group was introduced to the Mind Manager. The experimental group worked with the SMILE Maker Tool. Both groups are confronted to ill-structured case. Students fill in a questionnaire constructed to capture their reflections on the problem solving method, learning environment and interface of the tools.

8.1.2 Hypotheses

Based on the conceptualisation and research design the following set of hypotheses was formulated.

8.1.2.1 First hypothesis

The first hypothesis reflects the relationship between the two-level independent variable 'tool' and the dependent variable of 'performance on a case'.

Given an ill-structured case the experimental group using the SMILE Maker Tool will score higher than the control group, using the Mind Manager, on experts' judgment about successful solution.

8.1.2.2 Second hypothesis

The second hypothesis reflects the relationship between the independent variable and the dependent variable of mapping production. It is described by a set of more concrete assumptions. The operational definition of map production is similar to that used in Chapter 7. In the current experiment the dependent variable was operationalised by the same criteria of broad perception, divergency, convergency and planning but the scoring scheme was modified. It included some experts' judgment on a scale identifying the value they attribute to a particular indicator.

- **Broad Perception** (the extent to which experimental subjects elicit, represent and reflect comprehensively the problem situation)
  - Number of nodes – the total number of nodes (ideas) mapped in the collection of information map.
  - Fluency of nodes – represents how broadly the problem is elicited and represented according to an expert' scale '1(lowest)- 5(highest)' degree.
  - Variety of nodes – how many different types of nodes (in terms of facts, assumptions, feelings, and metaphors) are used.
  - Flexibility of nodes – represents the depth to which the students elicit and represent the situation according to an expert's scale '1(lowest)- 5(highest)'.
  - Number of labels – the total number of labels between the nodes in the map information collection.
  - Variety of labels – how many different types of labels (descriptive, structural causal, interrogative, and metaphorical) are used.
  - Flexibility of labels – the extent to which the students reflect the complexity of situation. An expert criterion on the scale '1(lowest)- 5(highest)' is applied here.
- **Divergency** (the extent to which ideas are elicited, reflected, represented and changed)
  - Number of ideas – the total number of ideas generated.
  - Diversity of ideas – expert assessment on a scale '1(lowest)- 5(highest)'.
  - Originality of ideas – expert evaluation on a scale '1(lowest)- 5(highest)'.
- **Convergency** (the extent to which the experimental subjects elicit and represent a comprehensive number of criteria for selecting ideas and extent to which they select a relevant solution)
  - Number and comprehensiveness of selection criteria – expert' evaluation on a scale '1(lowest)- 5(highest)'.
  - Adequacy of selection – expert's assessment on a scale '1(lowest)- 5(highest)'.
- **Planning** (the extent to which students elicit, represent and reflect on positive and negative factors, attribute preventive actions and make a plan). All sub-scales are based on an expert assessment where '1' is the lowest and '5' is the highest degree.
  - Forecasting the positive factors
  - Forecasting the negative factors
  - Planning preventing actions

- Planning steps for solving the problem
- Comprehensiveness of the planning

The formulations of the following hypotheses reflect the analysis of the Mind Manager in Chapter 4 (Section 4.2.4) and the characteristics of the SMILE Maker Tool.

Hypothesis II

In term of mapping production*:*

II.1 Both the experimental and the control group will score equally on the indicator 'numbers of nodes', 'fluency of nodes' and 'number of links' of the criteria of broad perception.

II.2 The experimental group will score higher than the control group on the indicators 'diversity of information items ('variety of nodes', 'flexibility' of nodes') and the 'diversity of links' ('variety of labels' and 'flexibility of labels') of the criteria of broad perception.

II.3 The experimental group will score higher than the control group on the indicator 'number of ideas', 'diversity of ideas', and 'originality of ideas' of the divergency criteria.

II.4 The experimental group will score higher than the control group on the indicators 'selection criteria', and 'selection of ideas' of the criteria of convergency.

II.5 The experimental group will score higher than the control group on the indicators 'forecasting positive factors for implementation', 'forecasting negative factors for implementation', 'listing preventive actions', 'planning the steps' and 'plan comprehensiveness' of the criteria of planning.

A few assumptions are formulated based on the presumed relationships between map production and the final solution of the case. It is hypothesised that:

II.6 There should be a relationship between the scores on mapping production and performance on the case.

Some relationships are assumed to exist between different criteria of the mapping production.

II.7 There should be a relationship between scores on broad perception and divergency of mapping production, between scores on broad perception and scores on planning and between scores on divergency and scores on convergency.

8.1.2.3 Third hypothesis

This hypothesis attempts to identify the degree to which the independent variable affects the dependent variable of users' reflections on the problem solving method implemented in the tools as measured by a reflective questionnaire.

In terms of responses to the Reflective Questionnaire*:*

III.1 The subjects in the experimental group will score higher than the control group subjects on the 'knowledge eliciting' items of the 'Method' scale.

III.2 The experimental group will score higher than the control group on the "knowledge creating' items of the 'Method' scale.

III.3 The experimental group will score higher than the control group on the 'knowledge reflecting' items of the 'Method' scale.

III.4 The experimental and the control group will score equally on the 'knowledge representing' items of the 'Method' scale.

III.5 There should be a relationship between scores on 'knowledge eliciting' and scores on 'knowledge creating', scores on 'knowledge reflecting' and scores on 'knowledge creating, scores on 'knowledge eliciting' and scores on 'knowledge reflecting'.

III.6 The experimental group will score higher than the control group on the item of 'explicit support for method' of the 'Method' scale.

8.1.2.4 Fourth hypothesis

This hypothesis attempts to identify the degree to which the independent variable affects the dependent variable of users' reflection on the learning environments of the tools as measured by a reflective questionnaire.

In terms of responses to the Reflective Questionnaire*:*

IV.1 The experimental group will score higher then the control group on the sub-scale 'explanation' of the scale 'learning environment'.

IV.2 The experimental group will score higher than the control group on the sub-scale 'examples'.

IV.3 The experimental group will score higher than the control group on the item 'procedures'.

IV.4 Both the experimental and the control group will score equally on the sub-scale of 'practice'.

IV.5 The experimental group will score higher than the control group on items indicative for individual approach, learnability and support for studying the method.

IV.6 The control group will score higher than the experimental group on the items indicative for easy learning of the graphical editor.

IV.7 There should be a relationship between scores on 'learning environment' items and the scores on case performance.

8.1.2.5 Fifth hypothesis

This hypothesis attempts to identify the degree to which the independent variable affects the dependent variable of users' reflections on the interface of the tools as measured by the Reflective Questionnaire.

In terms of the responses to the Reflective Questionnaire:

V.1 The control group will score better than the experimental group on the items of the 'interface' sub- scale indicative for the attractiveness of the tool, graphical editor interface and affordance.

V.2 The control group will score better than the experimental group on items indicative for a good navigation.

8.1.3 Experimental subjects

The experimental subjects were selected via the procedure of sequential sampling (Krathwohl, 1993). The process started with a small sample and continued until 47 students were assembled. This was the maximum number of participants we were able to collect. Finding students willing to take part in the experiment was one of the most difficult parts of the experiment. The following groups of students took part in the experiment:

- Undergraduate students from the University of Twente, the Netherlands -16
- MSc students from the Free University of Brussels, (Belgium) – 15 (17 selected, 2 dropped)
- Undergraduate students from the University of Economics and Management - UEM (Sofia, Bulgaria) – 16 (17 selected, 1 dropped)

The sequential sampling can be defined as probabilistic as far as at a certain stage there was a randomisation. The students were randomly assigned to the experimental and the control group (See Table 9). The following groups of students were formed:

Table 9. Distribution of the students in the experimental and the control group

		Experimental group ***N = 26***	Control group ***N = 21***
Learning Style	Explanation	6	5
	Examples	7	6
	Procedures	9	6
	Practice	4	4
Problem Solving Style	Seeker	4	4
	Diverger	8	6
	Converger	8	6
	Implementer	6	5
Learning Locus of Control	External	17	9
	Internal	9	12

8.1.4 Procedure

The procedure of this experiment included the following stages (see Appendix 22 for the description received by the subjects):

1. The students were randomly assigned to the control and the experimental group.
2. The students were asked to fill in the Style Inventory (see Appendix 20).
3. The experimental group was shortly introduced to the SMILE Maker Tool and the control group was introduced to Mind Manager.
4. A short training for the graphical editors in both tools was organized.
5. An ill-structured case was presented (‘George Career Dilemma’, see Appendix 17).
6. The students from both the control and experimental groups were asked to solve a case, using the mapping tools. They worked individually.
7. The students from both experimental and control groups were asked to fill in the Reflective Questionnaire (see Appendix 21).

8.1.5 Instruments

Several measuring instruments were used for the purposes of this experiment.

1. A Reflective Questionnaire (see Appendix 21) with three scales: method, learning environment, and interface
2. A Styles Inventory (see Appendix 20) with three scales: learning styles, problem solving styles and learning locus of control
3. A case – ‘George’s Career Dilemma’ (see Appendix 17).
4. Mapping production scoring scheme (see Section 8.1.2.2 and Appendix 16).

Chapter 6 'The methodology of the SMILE Maker evaluation' provided information about these research instruments.

8.1.6 Results

In this section the hypotheses are stated again but together with data. Analysis of the variance (ANOVA) is the statistical procedure applied on the data (See Sections 8.1.6.1 – 8.1.6.5). The ANOVA procedure should indicate if the variance between groups is significantly higher than intra- group variance. In addition regression analysis was applied in order to measure the effects of mediator variables on the relationship between 'tools' as independent variable and mapping production. (Raw data, regression analysis, and correlation analysis are presented in Appendices 24 – 28).

8.1.6.1 Hypothesis I

Given an ill-structured case the experimental group using the SMILE Maker Tool will score higher than the control group using the Mind Manager on an expert's judgment about successful solution.

Two experts independently analysed the solutions on the case giving a global grade between 5 and 10. The basis for their judgment was a master map and a solution got by them. The inter-coder reliability had the value of .96. The raw data of experts' judgment are given in Appendix 23. The means and standard deviation of the results on case solution are given in Table 10. The distribution of the scores over the learning styles, the problem solving styles and the learning locus of control are presented in Figures 31, 32 and 33.

Table 10. Scores on case solution – Descriptive and ANOVA data

	N	Mean	Std. Deviation
SMILE	26	7.4231	2.0673
MM (control)	21	5.5000	3.3242
Total	47	6.5638	2.8392

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	42.962	1	42.962	5.897	.019
Within Groups	327.846	45	7.285		
Total	370.809	46			

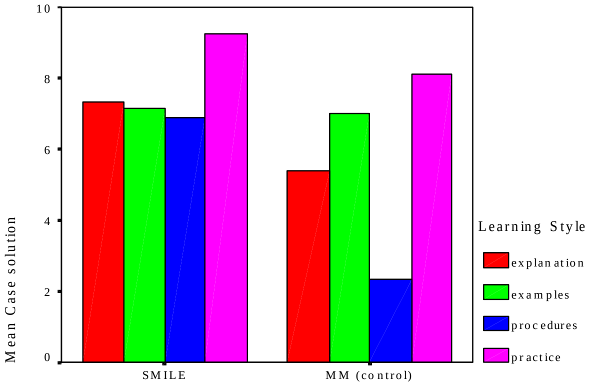


Figure 31. Scores on case solution, distributed over learning styles

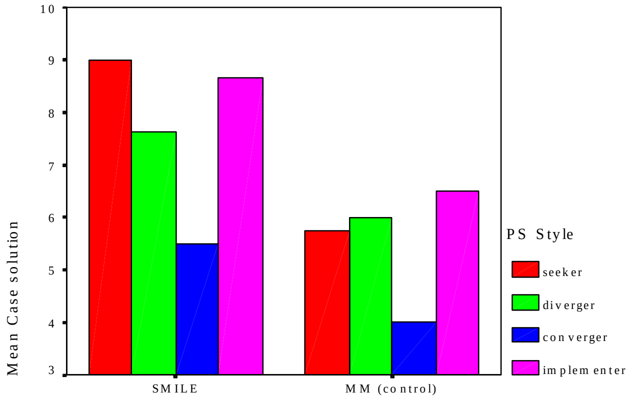


Figure 32. Scores on case solution, distributed over problem solving styles

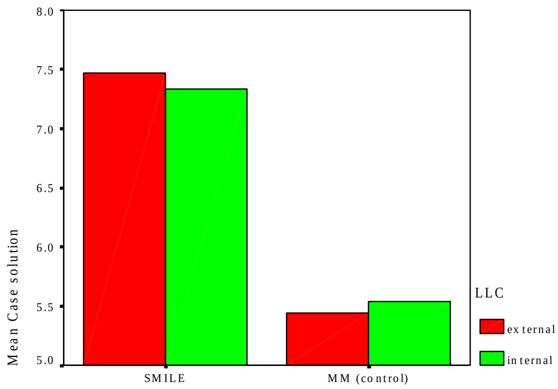


Figure 33. Scores on case solution, distributed over learning locus of control

The analysis of variance between the experimental and the control groups indicates that the former scores significantly higher – F (1, 45)= 5.897, p=.019, than the latter on an expert criterion for successful solution (see Table 10). Apparently the SMILE Maker Tool group benefited from the systematic approach for problem solving as a combination between mapping and creative problem solving techniques. More interpretations of this result are given in the Section 8.1.7 'Discussion'.

8.1.6.2 Hypothesis II

A number of sub-hypotheses reflected the relationship between the tools as independent variable and mapping production as a dependent variable. The expectations were based on the analysis in Chapter 4 of the existing mapping software and especially Mind Manager.

Hypothesis II reflected the effects of the two mapping tools on the mapping production. In order to describe in details the predicted relationships the hypothesis was formulated as a set of more concrete assumptions. Section 8.1.2.2 and Appendix 16 give an idea how maps were scored.

II.1 Given mapping production both the experimental and the control group will score equally on the indicator 'numbers of nodes', 'fluency of nodes' and 'number of links' of the criteria of broad perception.

Table 11. Fluency of Broad Perception

Dependent Variables		N	Mean	Std. Deviation
Total number of nodes	**SMILE**	26	17.5385	6.9985
	MM (control)	21	14.0952	6.8623
	Total	47	16.0000	7.0772
Fluency of nodes	**SMILE**	26	3.0769	.9021
	MM (control)	21	2.2381	1.0322
	Total	47	2.7021	1.0408
Total number of labels	**SMILE**	26	15.3846	7.2943
	MM (control)	21	8.0476	7.4597
	Total	47	12.1064	8.1674

Dependent Variables		Sum of Squares	df	Mean Square	F	Sig.
Total number of nodes	Between Groups	137.729	1	137.729	2.861	.098
	Within Groups	2166.271	45	48.139		
	Total	2304.000	46			
Fluency of nodes	Between Groups	8.174	1	8.174	8.830	.005
	Within Groups	41.656	45	.926		
	Total	49.830	46			
Total number of labels	Between Groups	625.362	1	625.362	11.519	.001
	Within Groups	2443.106	45	54.291		
	Total	3068.468	46			

- No significant difference was found on the indicator 'total number of nodes' – $F(1, 45) = 2.861$, $p = .098$. The SMILE Maker Tool group shows significantly better results on the indicator 'fluency of nodes' – $F(1, 45) = 8.830$, $p = .005$, than the group of the Mind Manager. (See Table 11 and Appendix 25)
- On the indicator 'number of labels' students in the experimental group score significantly higher than students in the control group – $F(1, 45) = 11.519$, $p = .001$.
- The expectation was that both tools lead to producing an almost equal number of nodes and links based on the fact that the Mind Manager supports free association and associations are always anchored to the central concept with links. However as data

shows the method that the SMILE Maker Tool group applies was more productive in the number of labels than the Mind Manager group. (See Table 11 and Appendix 25)

II.2 In term of map production the experimental group will score higher than the control group on the indicators 'diversity of information items ('variety of nodes' and 'flexibility' of nodes') and the 'diversity of links' ('variety of labels' and 'flexibility of labels') of the criteria of broad perception.

Table 12. Variety and Flexibility of Broad Perception

Dependent Variables		N	Mean	Std. Deviation
Variety of nodes	SMILE	26	3.6923	.9703
	MM (control)	21	3.0476	1.3220
	Total	47	3.4043	1.1732
Flexibility of nodes	SMILE	26	3.0769	1.0926
	MM (control)	21	2.2857	1.2306
	Total	47	2.7234	1.2105
Variety of links	SMILE	26	2.4231	.5778
	MM (control)	21	1.9524	.7400
	Total	47	2.2128	.6896
Flexibility of labels	SMILE	26	1.9615	1.2800
	MM (control)	21	1.2857	.9562
	Total	47	1.6596	1.1846

Dependent Variables		Sum of Squares	df	Mean Square	F	Sig.
Variety of nodes	Between Groups	4.828	1	4.828	3.715	.060
	Within Groups	58.491	45	1.300		
	Total	63.319	46			
Flexibility of nodes	Between Groups	7.272	1	7.272	5.442	.024
	Within Groups	60.132	45	1.336		
	Total	67.404	46			
Variety of links	Between Groups	2.574	1	2.574	6.002	.018
	Within Groups	19.299	45	.429		
	Total	21.872	46			
Flexibility of labels	Between Groups	5.306	1	5.306	4.030	.051
	Within Groups	59.247	45	1.317		
	Total	64.553	46			

- The analysis of variance (ANOVA) shows better results, but not a significant difference of the SMILE Maker group on the indicator 'variety of nodes' – F (1, 45)= 3.715, p=.06, (See Table 12).
- On the criterion of 'flexibility of nodes' a significant difference in favour of SMILE Maker Tool group was found – F (1, 45)= 5.442, p=.024. (See Table 12 and Appendix 25).

- The experimental group scored significantly better than the control group on the indicator 'variety of links' – F (1, 45)= 6.002, p=.018. (See Table 12 and Appendix 25).
- On the indicator 'flexibility of labels' a difference close to significant was found F (1, 45)= 4.030, p=.051). (See Table 12 and Appendix 25).

The results support the expectation that the use of the SMILE Maker Tool and the SMILE Method provides a broad and deep perception of problem situation. Different types of problem solving representations (objective and subjective) and variety of relationships (descriptive, structural, causal and metaphorical) show the complexity of problem situations. Perception plays an important role in problem solving as far as if the perception is inadequate then the following logical and reasoning processes are condemned to failure.

II.3 In term of map production the experimental group will score higher than the control group on the indicator 'number of ideas', 'diversity of ideas, and 'originality of ideas' of the divergency criteria.

Table 13. Divergency

Dependent Variables		N	Mean	Std. Deviation
Total number of ideas	SMILE	26	7.5000	6.5620
	MM (control)	21	4.1905	4.8951
	Total	47	6.0213	6.0487
Diversity of ideas	SMILE	26	2.8462	1.6418
	MM (control)	21	1.9048	1.5781
	Total	47	2.4255	1.6648
Originality of ideas	SMILE	26	2.3077	1.4905
	MM (control)	21	1.4286	1.3628
	Total	47	1.9149	1.4866

Dependent Variables		Sum of Squares	df	Mean Square	F	Sig.
Total number of Ideas	Between Groups	127.241	1	127.241	3.680	.061
	Within Groups	1555.738	45	34.572		
	Total	1682.979	46			
Diversity of Ideas	Between Groups	10.295	1	10.295	3.953	.053
	Within Groups	117.194	45	2.604		
		127.489	46			
Originality of Ideas	Between Groups	8.978	1	8.978	4.359	.042
	Within Groups	92.681	45	2.060		
	Total	101.660	46			

- The score of the experimental group on the indicator 'number of ideas' is higher, but not significantly – F (1, 45)= 3.680, p=.061. On the indicator 'diversity of ideas' the SMILE Maker group also showed better results near to the significant – F (1, 45)= 3.953, p=.053. The SMILE Maker is superior on the 'originality of ides' according to ANOVA – F (1, 45)= 4.359, p=.042. (See Table 13 and Appendix 25).

The result confirms partly the expectation. Both tools stimulate equally the generation of many and diverse ideas. Mind Manager claims to have a natural power for idea generation. The number of creative techniques based on the specifics of mapping that the SMILE Maker Tool offers led to more originality in the production of ideas.

II.4 In term of map production, the experimental group will score higher than the control group on the indicators 'selection criteria', and 'selection of ideas' of the criteria of convergency.

Table 14. Convergency

Dependent Variables		N	Mean	Std. Deviation
Selection criteria	SMILE	26	1.9231	1.8094
	MM (control)	21	.9524	1.1170
	Total	47	1.4894	1.5999
Selection	SMILE	26	2.5000	1.8601
	MM (control)	21	1.5238	1.4703
	Total	47	2.0638	1.7496

Dependent Variables		Sum of Squares	df	Mean Square	F	Sig.
Selection criteria	Between Groups	10.946	1	10.946	4.612	.037
	Within Groups	106.799	45	2.373		
	Total	117.745	46			
Selection	Between Groups	11.070	1	11.070	3.840	.056
	Within Groups	129.738	45	2.883		
	Total	140.809	46			

- The group of the SMILE Maker is significantly better on the indicator 'selection criteria' according to ANOVA – F (1, 45)= 4.612, p=.037. (See Table 14).
- On 'selection of ideas' indicator according to ANOVA the difference is close to significant – F (1, 45)= 3.840, p=.056. (See Table 14 and Appendix 25)

The expectations were based on the fact that the Mind Manager does not provide an explicit support for convergency. The SMILE Maker Tool groups show better results on 'selection' indicator and significant difference on 'selection criteria' indicator. This could be explained by the problem solving method implemented in the SMILE Maker Tool which offers extra techniques, procedures and templates for idea selection.

II.5 In term of map production, the experimental group will score higher than the control group on the indicators 'forecasting positive factors for implementation', 'forecasting negative factors for implementation', 'listing preventive actions', 'planning of the steps' and 'plan comprehensiveness' of the criteria of 'Planning'.

Table 15. Planning

Dependent Variables		N	Mean	Std. Deviation
Mapping positive factors	SMILE	26	1.3077	1.1923
	MM (control)	21	.6190	1.0235
	Total	47	1.0000	1.1610
Mapping negative factors	SMILE	26	1.6923	1.3121
	MM (control)	21	1.0000	.8944
	Total	47	1.3830	1.1851
Listing preventive actions	SMILE	26	1.1154	1.2434
	MM (control)	21	.4762	.6016
	Total	47	.8298	1.0492
Planning steps	SMILE	26	1.8077	1.4702
	MM (control)	21	.9048	1.4800
	Total	47	1.4043	1.5274
Plan comprehensiveness	SMILE	26	1.5577	1.0708
	MM (control)	21	.8571	.9103
	Total	47	1.2447	1.0523

Dependent Variables		Sum of Squares	df	Mean Square	F	Sig.
Mapping positive factors	Between Groups	5.509	1	5.509	4.389	.042
	Within Groups	56.491	45	1.255		
	Total	62.000	46			
Mapping negative factors	Between Groups	5.568	1	5.568	4.244	.045
	Within Groups	59.038	45	1.312		
	Total	64.606	46			
Listing preventive actions	Between Groups	4.746	1	4.746	4.654	.036
	Within Groups	45.892	45	1.020		
	Total	50.638	46			
Planning steps	Between Groups	9.471	1	9.471	4.356	.043
	Within Groups	97.848	45	2.174		
	Total	107.319	46			
Plan comprehensiveness	Between Groups	5.701	1	5.701	5.672	.022
	Within Groups	45.235	45	1.005		
	Total	50.936	46			

- The experimental group is significantly better for 'forecasting all positive factors' according to ANOVA – $F(1, 45) = 4.389$, $p = .042$. (See Table 15 and Appendix 25).
- SMILE Maker Tool group perform significantly better on the indicator 'forecasting all negative factors'– $F(1, 45) = 4.244$, $p = .045$ (See Table 15 and Appendix 25).
- The group of the SMILE Maker Tool is significantly superior on the indicator 'listing preventive actions' according to ANOVA – $F(1, 45) = 4.654$, $p = .036$. (See Table 15 and Appendix 25).
- The SMILE group proves to be significantly better after ANOVA – $F(1, 45) = 4.356$, $p = .043$ on the indicator 'planning the steps for implementation' (See Table 15 and Appendix 25).

- The results of the experimental group on the indicator ‘plan comprehensiveness’ are also significantly higher according to ANOVA – $F(1, 45)= 5.672$, $p=.022$ (See Table 15 and Appendix 25).

The superiority of the SMILE Maker comes from the explicit support for ideas implementation it provides. The implementation depends on the extent to which all positive and negative factors are listed, preventive actions are assigned and a plan is scheduled.

The assumptions II.6 and II.7 were formulated based on the presumed relationships between map production and the final solution of the case, and between different components of the map production.

II.6 There should be a relationship between the scores on mapping production and performance on the case.

The data show strong positive correlations between the final solution of the case and the ‘broad perception’, ‘divergency’, ‘convergency’ and ‘planning’ criteria. The higher the score on the different components of the mapping production, the higher the score on the final solution. The following data appeared after a correlation analysis (Pearson Correlation Coefficient) (see Appendix 27):

- *Final solution and criteria of* **‘***broad perception’*. There is a significant positive correlation on the final solution and following indicators of broad perception: ‘total number of nodes’ (r =.358, p=.014) ‘fluency of nodes’ (r =.636, p=.00), ‘flexibility of nodes’ (r =.603, p=.00), ‘number of labels’ (r =.431, p=.002), and ‘flexibility of labels’ (r = .598, p=.00).

- *Final solution and criteria of ‘divergency’*. There is a significant positive correlation of the final solution with all indicators of ‘divergency’: ‘total number of generated ideas’ (r =.612, p=.00), ‘diversity of ideas’ (r =.778, p=.00) and ‘originality of ideas’ (r =.753, p=.00).

- *Final solution and ‘convergency’*. There is a significant correlation of the final solution and the following indicators of ‘convergency’: ‘listing the selection criteria’ (r =.309, p=.035), and ‘selection of ideas’ (r =.632, p=.00).

- *Final solution and criteria of ‘planning’*. There is a significant positive correlation of the final solution with following indicators of ‘planning’ criteria: ‘forecasting the positive factors’ (r =.320, p=.028), ‘planning the preventing actions’ (r =.423, p=.003), ‘planning’ of the steps for implementation’ (r =.498, p=.00), and ‘plan comprehensiveness’ (r =.564, p=.00).

The high correlation between the score on solving a case and the map production proves statistically the expectation that solving ill-structured cases is highly dependent on how broad and deep the perception of a problem situation is, how fluent and flexible is the generation of ideas, how effective is the choice of an adequate solution, and how feasible is the implementation of a solution.

II.7 There should be a relationship between scores on broad perception and divergency of mapping production, scores on broad perception and scores on planning, and between scores on divergency and scores on convergency.

- The data revealed a positive correlation between scores on 'broad perception' and 'divergency' (see Appendix 27).
  - There is a strong positive correlation between the 'fluency of nodes' and all indicators of the 'divergency': 'number of ideas' (r =.560, p=.00); diversity of ideas' (r =.520, p=.00); 'originality of ideas' (r =.419, p=.003)
  - There is a significant positive correlation between the 'flexibility of nodes' and the indicator of 'diversity of ideas' of 'divergency' criterion (r =.351, p=.016).
  - There is a significant correlation between the 'total number of labels' and all indicators of 'divergency': 'number of ideas' and 'number of labels' (r =.452, p=.00); 'diversity of ideas'(r =.356, p=.014); and 'originality of ideas' (r =.298, p=.042).
  - There is a significant positive correlation between the 'flexibility of labels' and all indicators of 'divergecy': 'number of ideas' (r =.559, p=.00); 'diversity of ideas' (r =.670, p=.00); 'originality of ideas' (r =.712, p=.00)

Basically, the correlation between 'broad perception' and 'divergency' confirms the assumption for the existence of a connection between the extent to which the complexity of problem situation is represented adequately and the number and the originality of the ideas. However some results are surprising and need more attention. No significance is reported for the following relationships:

- There is not a significant correlation between number of nodes and all indicators of 'divergency', respectively: 'number of ideas' (r =.234, p =.113); 'diversity of idea' (r =.181, p =.224) and 'originality of ideas' (r =-.004, p =.978) (See Appendix 27). The quantity of information items in map information collection did not significantly affect the diversity and originality of the ideas in map idea generation. What matter really are the types of information items and the types of relationships between them, not the number of nodes.

- There is not significant correlation between the 'flexibility of nodes' and the indicators of 'divergency' - 'number of ideas' (r = .286, p =.051) and 'originality of ideas' (r =.240, p =.104). One possible explanation is that there should not be a direct connection between 'flexibility of nodes' and 'number of ideas'. It is more logical to expect a connection between 'flexibility of nodes' and 'originality of ideas'. However the result also shows no significant difference between those indicators. A probable reason for this might be the fact that students in the experimental group applied only one or two of the proposed techniques for idea generation. It is possible that they did not use the technique 'pair' which is based on the variety of nodes.
- The same reason could be applied as an explanation for the existence of positive, but no significant correlation between the 'variety of labels' and the 'originality of ideas' (r = .251, p =.088), and 'diversity of ideas' (r = .260, p =.077). One of the proposed techniques in the idea generation phase is 'changing labels' which is based on the variety of labels in map information collection. The techniques for idea generation are too much for one experimental session and students choose only one or maximum two of them.
- There is a strong positive correlation between scores on broad perception and planning (see Appendix 27).
  - There is a significant correlation between 'fluency of nodes' and the following components of planning: 'listing positive factors' (r =.378, p=.009); 'planning preventive actions' (r =.500, p=.00); 'planning the steeps'(r =.556, p=.00); 'comprehensiveness of planning' (r =.644, p=.00).
  - The significant correlation was found also between 'flexibility of nodes' and 'comprehensiveness of planning' (r =.430, p=.003); and 'planning preventive actions' (r = .322, p=.028).

The SMILE Maker suggests that problem solvers should start to think about implementation of a solution at the very early stages of problem solving. Identifying all factors that could play an important role during information collection phase would prove useful for the idea implementation phase as well as.

- There is a significant positive correlation between all components of the 'divergency' and all components of the 'convergency' (see Appendix 27). Respectively:
  - 'Selection of ideas' and 'number of ideas' (r =.503, p=.00), 'diversity of ideas'(r =.677, p=.00), and 'originality of ideas' (.813, p=.00)
  - 'Explicit selection criteria' and 'number of ideas' (r =.428, p=.003), 'diversity of ideas' (r = .287, p=.050), and 'originality of ideas' (r =.365, p=.012)

'Divergency' and 'convergency' reflect two important phases of the SMILE Maker problem solving method. The method supports generation of ideas but also selection of the most appropriate solutions among the produced ideas. Apart from that the method requires in each of the stages of problem solving both divergent and convergent activities to be organised. Convergent activities always follow divergent activities.

8.1.6.3 Hypothesis III

This hypothesis reflects how the independent variable affects the scores on the scale of 'method' on the Reflective Questionnaire. The hypothesis like the previous one was described as a set of more concrete sub-hypotheses. The analysis of variance (ANOVA) is the statistical procedure used for analysing of the data.

Table 16. Reflective Questionnaire – scale Method

Dependent Variables		N	Mean	Std. Deviation
Knowledge Eliciting	SMILE	26	41.6154	8.4004
	MM (control)	21	37.2381	7.3614
	Total	47	39.6596	8.1701
Knowledge Creating	SMILE	26	23.3846	5.4264
	MM (control)	21	19.6190	6.4457
	Total	47	21.7021	6.1358
Knowledge Reflecting	SMILE	26	24.8462	6.1037
	MM (control)	21	19.9524	5.7834
	Total	47	22.6596	6.3905
Knowledge Representing	SMILE	26	15.2692	2.0892
	MM (control)	21	13.3333	2.7080
	Total	47	14.4043	2.5509

Dependent Variables		Sum of Squares	df	Mean Square	F	Sig.
Knowledge Eliciting	Between Groups	222.590	1	222.590	3.517	.067
	Within Groups	2847.963	45	63.288		
	Total	3070.553	46			
Knowledge Creating	Between Groups	164.724	1	164.724	4.730	.035
	Within Groups	1567.106	45	34.825		
	Total	1731.830	46			
Knowledge Reflecting	Between Groups	278.216	1	278.216	7.823	.008
	Within Groups	1600.337	45	35.563		
	Total	1878.553	46			
Knowledge Representing	Between Groups	43.537	1	43.537	7.660	.008
	Within Groups	255.782	45	5.684		
	Total	299.319	46			

III.1 In term of responses to the Reflective Questionnaire, the subjects in the experimental group will score higher than the subjects in the control group on the 'knowledge eliciting' type of items of the 'Method' scale.

There is no significant difference on the indicator eliciting according to ANOVA – F (1, 45)= 3.517, p=.067, even the SMILE Maker students perform better. (See Table 16, and Figure 34).

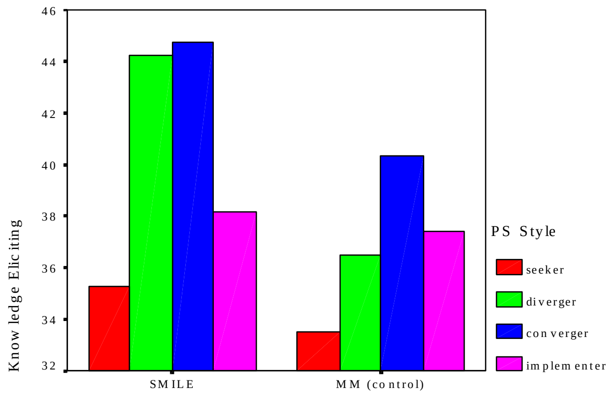


Figure 34. Knowledge eliciting

III.2 The experimental group will score higher than the control group on the 'knowledge creating' type of items of the 'Method' scale.

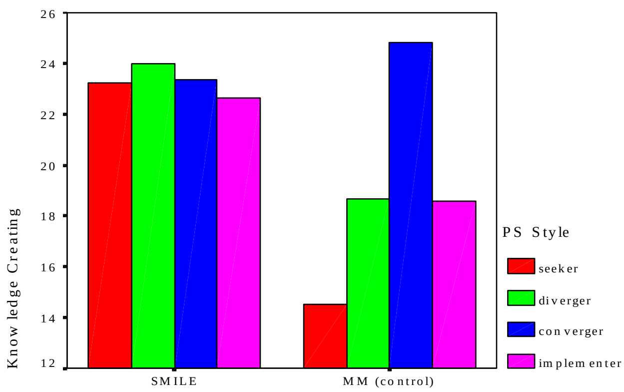


Figure 35. Knowledge creating

The score of the SMILE Maker Tool group was significant higher than the Mind Manager group. The ANOVA indicates value of F (1, 45)= 4.730, p=.035 (See Table 16, Figure 35).

III.3 The experimental group will score higher than the control group on the 'knowledge reflecting' type of items of the 'Method' scale.

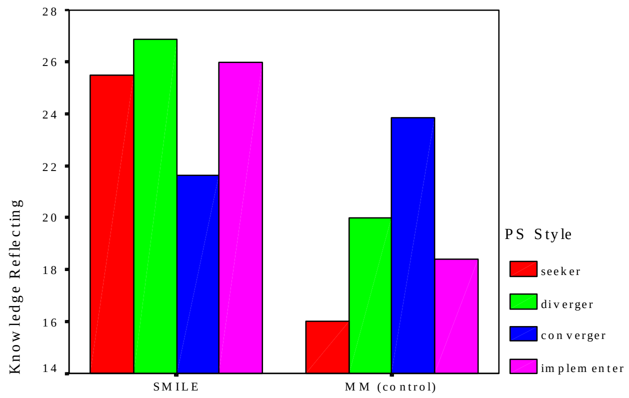


Figure 36. Knowledge reflecting

According to ANOVA - F (1, 45)= 7.823, p=.008, the score of the experimental group is significantly higher (See Table 16, Figure 36).

III.4 The experimental and the control group will score equally on the 'knowledge representing' group of items of the 'Method' scale.

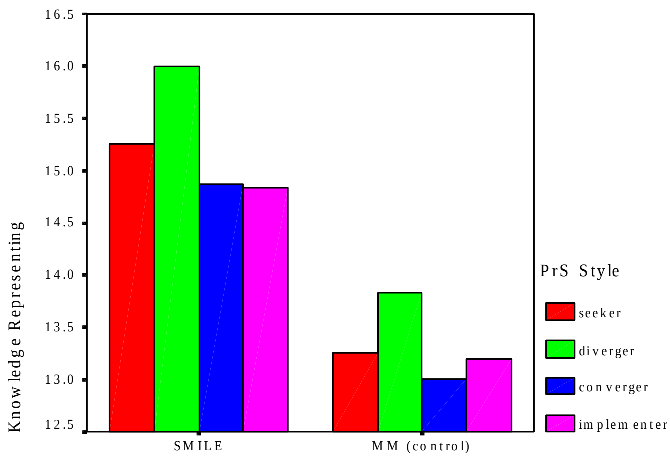


Figure 37. Knowledge representing

The experimental group is significantly better on this indicator according to ANOVA – F (1, 45)= 7.660, p=.008. (See Table 16, and Figure 37).

The lack of significance about 'knowledge eliciting' could be explained by two reasons. Firstly, free association is embedded in the mind mapping method although it is the only technique for eliciting in the Mind Manager. The SMILE problem solving method proposes several techniques but the experimental subject had time only to look at one or a few of them. The first technique the tool suggests is 'free association'. The difference in favour of the SMILE Maker Tool, although not significant, is due may be to the explicitness of the support that the tool provides. Secondly, the interface of the Mind Manager is quite attractive for supporting eliciting of information items and it contributes strongly to the positive perception of the subjects from the control group. This result should be checked against the outcomes of the hypotheses reflecting map production. The indicators such as ‘fluency of nodes’, ‘flexibility of nodes’, ‘diversity of ideas’, ‘number of selective criteria’, ‘forecasting positive factors’, and ‘forecasting negative factors’ are some sorts of operationalisations of the concept of ‘knowledge eliciting’. On these indicators the SMILE Maker is a significantly better tool.

The significance in favour of the SMILE Maker group on knowledge reflection and knowledge representation was not expected because the metaphor of map applied in both tools should have been a strong factor for both. The difference could be attributed to the specific means of the knowledge representation in both tools. The SMILE Maker supports a variety of problem solving representations and a variety of relationships between them. The opportunity to attach labels on the links in order to describe the complex relationships in ill-structured situations is probably an essential factor contributing to the result. Another reason could be that knowledge representation, knowledge reflection, knowledge elicitation and knowledge creation are mutual beneficial to each other. Each of them amplifies the effect of others. The significant difference for knowledge creation was expected because the SMILE Maker Tool offers more techniques for knowledge creation.

III.5 There should be a relationship between scores on ‘knowledge eliciting’ and scores on ‘knowledge creating’, scores on ‘knowledge reflecting’ and scores on ‘knowledge creating, scores on ‘knowledge eliciting’ and scores on ‘knowledge reflecting’scale.

Table 17. Correlation between the elements of the Method’s sub-scales

		2. Creating	3. Reflecting	4. Representing
1. Eliciting	Pearson Correlation	.517	.410	.212
	Sig. (2-tailed)	.000	.004	.152
	N	47	47	47
2. Creating	Pearson Correlation		.845	.159
	Sig. (2-tailed)		.000	.285
	N		47	47
3. Reflecting	Pearson Correlation			.127
	Sig. (2-tailed)			.394
	N			47

The data show positive correlations between scores on ‘knowledge eliciting’ and ‘knowledge creating’(r=.517, p=.00); ‘knowledge reflecting’ and ‘knowledge creating’(r =.845, p=.00); ‘knowledge eliciting’ and ‘knowledge reflecting’(r =.410, p=.004); (See Table 17 and Appendix 28)

The high correlation between knowledge elicitation, reflection, and creation shows that these factors are very much related to each other. The good performance in eliciting of knowledge items leads to a success in creating of ideas and enhances the reflection on a problem solving space. The reflection is a good basis for creating of ideas. Knowledge elicitation, knowledge representation, knowledge reflection and knowledge creation are the main characteristics of a hypothetical construct assumed to explain how and why the SMILE Method might be a good solution for solving design problems. More interpretation about the construct is given in section 8.1.7 'Discussion'.

III.6 The experimental group will score higher than the control group on the item' explicit support for the method' of the 'Method' scale.

Table 18. Explicit support for the method

Dependent Variable		**N**	**Mean**	**Std. Deviation**
Explicit support for the method	SMILE	26	21.6923	4.4611
	MM (control)	21	18.2381	5.2431
	Total	47	20.1489	5.0776

Dependent Variable		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Explicit support for the method	Between Groups	138.609	1	138.609	5.955	.019
	Within Groups	1047.348	45	23.274		
	Total	1185.957	46			

There is a significant difference in favour of the SMILE group (ANOVA – $F(1, 45) = 5.955$, $p=.019$) (See Table 18). The reason may be that the SMILE Maker Tool explicitly provides a systematic approach for solving design problems.

8.1.6.4 Hypothesis IV

This hypothesis predicts the effects of the two level independent variable of 'tool' on the scores on the scale of 'learning environment' of the Reflective Questionnaire. It follows the same style of formulation as the previous hypothesis.

Table 19. Reflective Questionnaire – scale Learning environment

Dependent Variables		**N**	**Mean**	**Std. Deviation**
Explanation	SMILE	26	3.5385	1.2403
	MM (control)	21	2.8571	1.0142
	Total	47	3.2340	1.1835
Examples	SMILE	26	3.5000	.9487
	MM (control)	21	3.0000	.9487
	Total	47	3.2766	.9714

Dependent Variables		N	Mean	Std. Deviation
Procedures	SMILE	26	3.9231	.7442
	MM (control)	21	3.2381	1.4108
	Total	47	3.6170	1.1335
Practice	SMILE	26	4.0000	.9798
	MM (control)	21	3.8571	.9103
	Total	47	3.9362	.9419
Individual Approach	SMILE	26	7.4615	1.8597
	MM (control)	21	5.7143	2.0036
	Total	47	6.6809	2.0966
Learnability	SMILE	26	6.5385	1.7716
	MM (control)	21	5.0952	2.0953
	Total	47	5.8936	2.0348
Support for studying the Method	SMILE	26	3.9231	1.2938
	MM (control)	21	2.9048	1.6403
	Total	47	3.4681	1.5301
Support for Graphical Editor	SMILE	26	4.1154	.5883
	MM (control)	21	4.1429	.9636
	Total	47	4.1277	.7694

Dependent Variables		Sum of Squares	df	Mean Square	F	Sig.
Explanation	Between Groups	5.393	1	5.393	4.111	.049
	Within Groups	59.033	45	1.312		
	Total	64.426	46			
Examples	Between Groups	2.904	1	2.904	3.227	.079
	Within Groups	40.500	45	.900		
	Total	43.404	46			
Procedures	Between Groups	5.451	1	5.451	4.571	.038
	Within Groups	53.656	45	1.192		
	Total	59.106	46			
Practice	Between Groups	.237	1	.237	.263	.611
	Within Groups	40.571	45	.902		
	Total	40.809	46			
Individual approach	Between Groups	35.466	1	35.466	9.571	.003
	Within Groups	166.747	45	3.705		
	Total	202.213	46			
Learnability	Between Groups	24.197	1	24.197	6.549	.014
	Within Groups	166.271	45	3.695		
	Total	190.468	46			
Support for studying the Method	Between Groups	12.046	1	12.046	5.667	.022
	Within Groups	95.656	45	2.126		
	Total	107.702	46			
Support for the Graphical Editor	Between Groups	8.768	1	8.768	.014	.905
	Within Groups	27.225	45	.605		
	Total	27.234	46			

The data were analysed using ANOVA and regression analysis for the mediator variables of learning style and learning locus of control.

IV.1 Given the responses to the Reflective Questionnaire the experimental group will score higher then the control group on the sub-scale 'explanation' of the scale 'learning environment'.

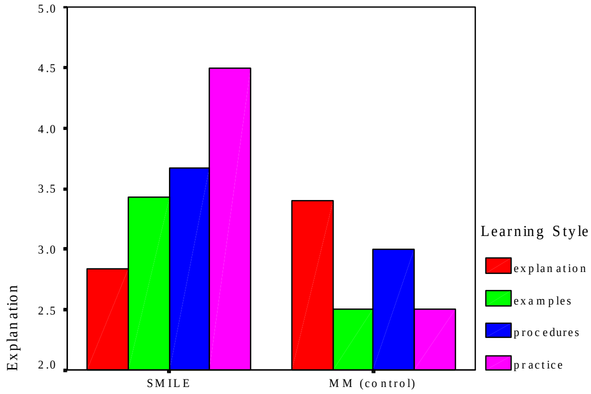


Figure 38. Explanation

There is a significant difference on the sub-scale 'explanation' in favour of the SMILE group – F (1, 45)= 4.411, p=.049. The result confirms the expectations based on lack of explicit support in the help system of the Mind Manager for what is the mind mapping and how it can be used in practice for solving problems. (See Table 19 and Figure 38)

IV.2 The experimental group will score higher than the control group on the sub-scale 'examples'

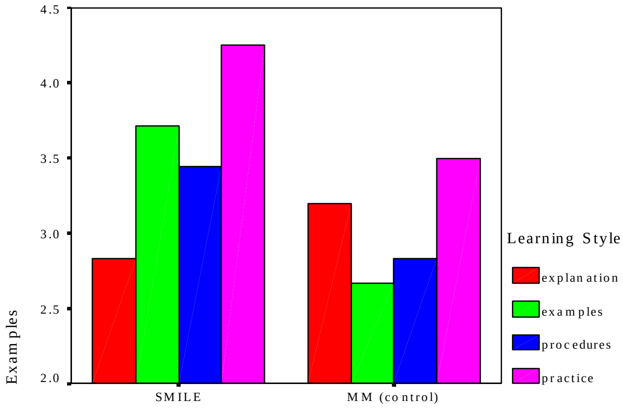


Figure 39. Examples

There was no significant difference on the sub-scale 'examples'. The assumption is confirmed as the result of the SMILE Maker group is higher according to ANOVA – F (1, 45)= 3.337, p=.079 (See Table 19 and Figure 39)

IV.3 The experimental group will score higher than the control group on the item 'procedures'.

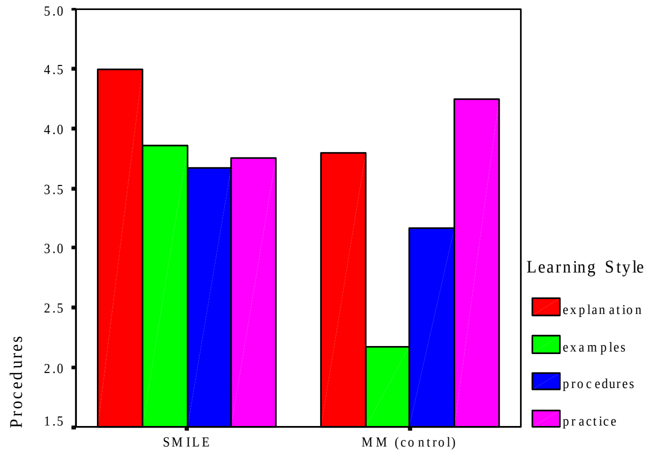


Figure 40. Procedures.

The SMILE group shows a significantly better result on the sub-scale of 'procedures' - F (1, 45)= 4.571, p =.038. (See Table 19 and Figure 40).

IV.4 Both the experimental and the control group will score equally on the sub-scale of 'practice'.

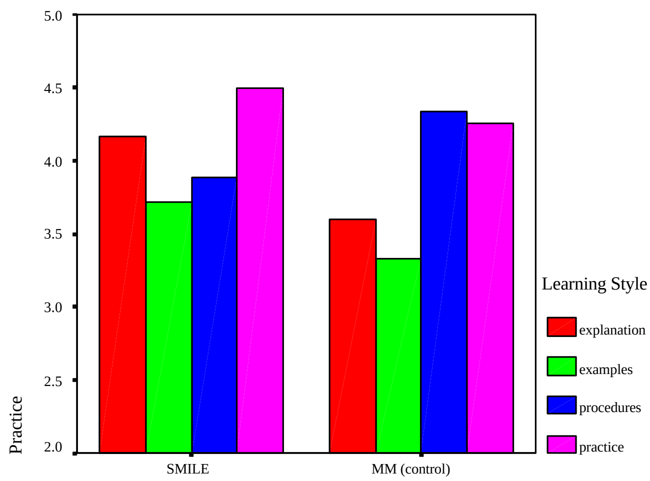


Figure 41. Practice

According to ANOVA - F (1, 45)= .263, p=.611) there is no significant difference on the sub-scale 'Practice'. (See Table 19 and Figure 41).

IV.5 The experimental group will score higher than the control group on items indicative for individual approach, learnability and support for studying the method.

The subjects in the SMILE Maker group performed significantly better – F (1, 45)= 9.571, p=.003 on the sub-scale of 'individual approach'. The SMILE Maker group showed a significant higher result on the 'learnability' sub-scale ('easy to understand'; 'self-study approach is sufficient for studying the method') according to ANOVA – F (1, 45) = 6.549, p=.014. The SMILE Maker group scored significantly better on the sub-scale of 'support for studying the method' – F (1, 45) = 5.667, p=.022. The results were expected as the learning environment of the SMILE Maker was deliberately designed to match instructional conditions to individual differences of users (See Table 19).

IV.6 The control group will score higher than the experimental group on the items indicative for easy learning of the graphical editor.

There was no significant difference on this indicator – F (1, 45) = .014, p =.905. The SMILE Maker does not provide an explicit support how to use the graphical editor. However it makes use of Inspiration software. It seems that the help system of the Inspiration for its graphical editor is useful at about the same extent as the help system of the Mind Manager (See Table 19).

IV.7 There should be a relationship between scores on 'learning environment' items and the scores on case performance.

Table 20. Correlation between subscales Learning environment and Case performance

	N	Mean	Std. Deviation
Sub-scale Learning Environment	47	33.5957	8.3214
Case performance	47	6.5638	2.8392

		Case performance
Sub-scale Learning Environment	Pearson Correlation	.316
	Sig. (2-tailed)	.031
	N	47

The scores on 'learning environment' sub-scales correlate significantly with the score on 'problem performance' according to Pearson Correlation, r =.316, p=.031 (See Table 20). The higher the satisfaction of people with the learning environment the higher the score on solving the case. A well-organized learning environment makes studying and applying the problem solving method more effective.

8.1.6.5 Hypothesis V

This hypothesis reflects the attitudes of users to the interface of the SMILE Maker Tool and the Mind Manager. The data were analysed using ANOVA. A set of assumptions describes in a more concrete term this hypothesis.

V.1 In term of the responses to the Reflective Questionnaire the control group will score significantly higher than the experimental group on the items of the 'Interface' sub-scale that are indicative for the attractiveness of the tool, graphical editor interface and affordance.

Table 21. Interface

Dependent Variables		N	Mean	Std. Deviation
Attractiveness	SMILE	26	4.3462	.5616
	MM (control)	21	4.5714	.5071
	Total	47	4.4468	.5441
Graphical editor	SMILE	26	3.8077	.8494
	MM (control)	21	3.8571	1.0142
	Total	47	3.8298	.9165
Affordance	SMILE	26	2.6923	1.1582
	MM (control)	21	2.6190	1.1170
	Total	47	2.6596	1.1282
Navigation	SMILE	26	10.0769	2.3987
	MM (control)	21	9.9524	2.6921
	Total	47	10.0213	2.5064
Interface total	SMILE	26	20.9615	3.5607
	MM (control)	21	20.8095	3.5584
	Total	47	20.8936	3.5216

Dependent Variables		Sum of Squares	df	Mean Square	F	Sig.
Attractiveness	Between Groups	.590	1	.590	2.036	.160
	Within Groups	13.027	45	.289		
	Total	13.617	46			
Graphical Editor	Between Groups	2.841	1	2.841	.033	.856
	Within Groups	38.610	45	.858		
	Total	38.638	46			
Affordance	Between Groups	6.2352	1	6.235	.048	.828
	Within Groups	58.491	45	1.300		
	Total	58.553	46			
Navigation	Between Groups	.180	1	.180	.028	.868
	Within Groups	288.799	45	6.418		
	Total	288.979	46			
Interface total	Between Groups	.268	1	.268	.021	.885
	Within Groups	570.200	45	12.671		
	Total	570.468	46			

The data show no significant difference on the item for interface attractiveness – $F(1, 45) = 2.036$, $p = .160$. There is no significant difference on the item for graphical editor interface – $F(1, 45) = .033$, $p = .856$ and affordance – $F(1, 45) = .048$, $p = .828$ (see Table 21). The possible explanation of these results is related to the way the statement was formulated in the reflective questionnaire. It may suggest reflection on the graphical editor but not on the tool itself. The difference between the graphical interfaces of the SMILE Maker and Mind Manager in favour of the Mind Manager is greater than the difference between the Inspiration and the Mind Manager.

V.2 The control group will score better than the experimental group on the items indicative for good navigation.

No significant difference is found on the navigation items – F (1, 45)= .028, p =.868 (see Table 21). The Mind Manager has well developed navigation system. The SMILE Maker compensates with the design solution based on ‘The Brain’ navigation window (See Section 4.11).

8.1.6.6 Regression analysis

In addition to the ANOVA statistics the regression analysis was conducted in order to control the effects of mediator variables such as problem solving style, learning style and learning locus of control. As a general tendency the results show that no one of them influenced significantly the main effect of the independent variable (see Appendix 26). After the regression analysis the difference between the two groups in some of the cases slightly increases in other - slightly decreased. On the most of the indicators the regression coefficient of the mediator variables did not exceed the coefficient of the independent variable. Only in a few cases the reported ANOVA significance was changed exceeding the probability level.

- On the following indicators ANOVA found no significant difference but after the regression analysis the coefficient difference was significant: ‘flexibility of labels’ (ANOVA p=.051, regression p=.036), ‘diversity of ideas’ (ANOVA p=.053, regression p=.049), selection of ideas (ANOVA p=.056, regression p=.030).
- In the opposite, on the indicator ‘planning negative factors’ a significant difference according ANOVA p=.045, was decreased by the regression analysis to p=.057)

As the examples presents the differences are marginal. It could be assumed that the changes are due to the boundary values rather than to a strong effect of the moderator variables. This means that the interaction effect is lower that the main effect.

8.1.7 Discussion

The purpose of this experiment was not to get data in order to claim that the SMILE Maker Tool is a better tool than Mind Manager but rather to say how and why the SMILE Maker might help people in solving design problems. It was aimed at providing quantitative data for answering the research question: *What is the quantitative and qualitative evidence that the SMILE Maker Tool is an effective tool for problem solving?* The analysis of the relationships between the independent variable of tool for problem solving (with two levels) and the dependent variables of solution of a case, mapping production and reflections on the process of problem solving provided promising evidence of what might make solving design problems a more successful activity. The research was designed to collect data about a method of problem solving, learning environments and the interface of the tools. The three factors are separated only for research purposes to identify the particular role and contribution of each of them. The question is what specifically about a method, learning environment and interface is essential for a tool to support people in solving design problems. This is discussed in Sections 8.1.7.1, 8.1.7.2, and 8.1.7.3.

8.1.7.1 Method

The SMILE Maker Tool proposes explicitly a framework for a systematic approach for problem solving consisting of several phases. Within each of them support is provided including specific techniques for information collection, idea generation, idea selection and idea implementation. Successful problem solving is a function of how broad and deep the problem space is perceived, how fluent are the divergent activities, how adequate is the convergence of ideas and how comprehensive and feasible is the implementation of solutions. However, more important is identifying the operational mechanism that makes this Method really workable. The four characteristics of the SMILE Problem Solving Method are knowledge elicitation, knowledge reflection, knowledge representation and knowledge creation. They could be recognized in each phase of the SMILE Problem Solving Method. In term of applying specific techniques, the SMILE Maker facilitates *eliciting* of appropriate knowledge, overcoming the negative problem solving syndrome, blocks and taboos. It retrieves not only the dominant thinking pattern but also all patterns that could have a role in solving a design problem. The SMILE Method stimulates generation of as many and diverse ideas as possible (nodes fluency– $F(1, 45) = 8.830$, $p = .005$ (Hypothesis II.1) and nodes flexibility – $F(1, 45) = 5.442$, $p = .024$ (Hypothesis II.2), based on the principle ‘quantity breads quality’. It also supports getting a comprehensive set of criteria for choosing the most appropriate candidate among ideas - $F(1, 45) = 4.612$, $p = .037$ (Hypothesis II.4), and collecting all factors that could promote $F(1, 45) = 4.389$, $p = .042$, or inhibit – $F(1, 45) = 4.244$, $p = .045$ the implementation of a solution (Hypothesis II.5). The SMILE Problem Solving Method implemented in the SMILE Maker Tool manages the complexity of the situation *representing* the flexibility of problem solving items (facts, feelings, intuitions, metaphors)– $F(1, 45) = 5.442$, $p = .024$ and variety of relationships between the components of a problem situation (descriptive, structural, causal, metaphorical) links' – F (1, 45)= 6.002, p=.018 (Hypothesis II.2). Mental maps are recognized as adequate, accurate and flexible way of expressing the way human mind organizes incoming information (See Section 4.13). They mirror the internal cognitive structure by realizing a close correspondence between them and the external mode of representation. The SMILE Maker Tool employs a simple, intuitive and compact graphical convention that could represent complex relationships. The externalisation of internal problem solving models extends the limited potential of working memory reducing the cognitive overload in ill-structured problem situations. Doing so the method simulates *reflection in* the process of problem solving and *reflection on* the results of problem solving - F (1, 45) = 7.823, p =.008 (Hypothesis III.3). The reflection may result in some changes in the organization of the problem solving space provoking creation of new knowledge. It is easy with the method to manipulate the knowledge items. The SMILE Maker Problem Solving Method suggests a combination of some of the substantial characteristics of mapping and the power of creative problem solving techniques in order to support the *creation* of new knowledge about problem definition, idea generation, idea selection, and solution implementation - F (1, 45) = .4730, p =.035 (III.2). The method is a consolidation between the two domains as the whole is more than the sum of the parts. The SMILE Maker Problem Solving Method offers some techniques such as 'scratch', 'pair', 'hot spot' and 'changing labels', which are synergy between mapping and problem solving. The strong positive correlation between knowledge elicitation, knowledge representation, knowledge reflection and knowledge creation evidences that the four characteristics are closely related to each other (Hypothesis III.5, See Table 17).

It is natural to expect that the good job resulting in the map production might be a strong predictor for the performance on the case and data proved that (Hypothesis II.6). The higher the results of broad perception, divergency, convergency, and planning, the higher is the final result in solving the case. The broader and deeper is exploration of the problem situation, the higher is the number of the original ideas generated, the higher is the probability of selecting the most appropriate solution, and the most feasible is the implementation of the solution. However, some of the data did not work at the expected direction. This could be attributed to some limitations of the experimental conditions.

8.1.7.2 Learning environment

The learning environment of the SMILE Maker Tool offers an explicit support for the SMILE Problem Solving Method F (1, 45) = 5.667, p =.022 (Hypothesis IV.5). Users have an opportunity to select their own ways of studying this method following one or few of the learning scenarios. A learning scenario builds a framework while the four learning events of explanation, examples, procedures and practice composed the operational mechanism that makes the learning environment of the SMILE Maker Tool successful. Each of the scenarios proposes a particular pattern of the four learning events. One of the strongest points of the SMILE Maker is the opportunity for individualization of the study. The SMILE Maker Tool's learning environment proposes just in time, just enough and at the point of need support. Different options for identifying people's learning preferences are suggested. Users could define their learning preferences through a questionnaire or just pick one or few learning events. The learning events constitute a strong basis for defining individual learning styles. Users have appreciated the individual approach offered by SMILE Maker Tool -$F(1, 45) = 9.571$, $p =.003$ (Hypothesis IV.5). The SMILE Maker Tool learning environment not only adapts instruction to learning styles but also tries to develop learning styles. Each content pattern that a user constructs is dominated by one of the learning events, but additional support is given for all other learning events.

8.1.7.3 Interface

There were not particular positive expectations about the interface of the SMILE Maker Tool. The general principle behind the graphical interface was 'simplicity is beauty' but the result was far from a good graphical interface. However the data were not so negative. The users appreciated the navigation solutions in the SMILE Maker Tool and Mind Manager at almost the same extent. What attracted the most of attention of the SMILE Maker Tool users were the navigation map, the possibility for synchronisation between the frames and the opportunity to know where you are while browsing.

8.1.8 Conclusions

The experimental validation of the SMILE Maker aimed at getting some quantitative data about the effectiveness of the tool. It was checked against performance on a case, mapping production and reflections of the experimental subjects on using the tool. In general it might be concluded that the SMILE Maker could be an effective tool for solving design problems because of at least two reasons:

- The SMILE Maker offers a systematic problem solving method that support knowledge elicitation, knowledge representation, knowledge reflection and knowledge creation during information collection, idea generation, idea selection and idea implementation.
- The SMILE Maker proposes to users an individualised learning environment for studying this method.

Apart from the experiment the evaluation of the SMILE Maker Tool involved another research method - a focus group interview.

8.2 Expert focus group

Expert Focus Group interviews are aimed at providing a qualitative data for answering the research question: *What is the quantitative and qualitative evidence that the SMILE Maker Tool is an effective tool for problem solving?* This section presents the sampling (8.2.1), subjects (8.2.2), procedure (8.2.3), and results (8.2.4) of the expert focus group research method.

A focus group is a data collection method based on a small group interview with informed people. The purpose of the method is to get high quality data where people consider their own opinions in the context of the views of others (Patton, 1990). Usually the participants are asked to reflect on the questions posed by the interviewer. Before giving their answers and comments they get to listen each other. The focus group method was selected for this research because of the following reasons:

- In a short period of time (1-2 hours) a researcher can get information from several informed people.
- It provides some quality controls on data collection, as participants tend to provide checks and balances on each other.
- The group's dynamics contributes to discussion of the most important topics.
- It is easy to access the extent to which there are relatively common and shared views among participants.
- Focus groups have proved to be highly enjoyable for people taking part in it (Patton, 1990).

8.2.1 Sampling

The focus group procedure involves purposeful sampling. The logic and the power of purposeful sampling lie in selecting information-rich cases for study in depth. Two types of purposeful sampling were applied to the focus group evaluation in the current research: maximum variations sampling and snowball sampling. Maximum variation sampling aims at capturing and describing the central themes that cut across a number of participants. Any common pattern that appears is of particular interest in capturing core-shared experiences (Patton, 1990). Snowballing is an approach to finding the key informants or critical case. By asking a number of people who else to be involved the snowball gets bigger.

8.2.2 Subjects

Fifty-five experts with different profiles took part in the focus group evaluation of the SMILE Maker Tool. The following groups were formed:

- University instructors: Faculty of Educational Science and Technology, University of Twente (educational and training designers); Faculty of Management and Technology, University of Twente (engineering design and creative problem solving); Faculty of Computer Science (software engineering design); Faculty of Psychology and Educational Science, Free University of Brussels (educational researchers); Faculty of Business Studies, Salford University, UK (organisational strategy; marketing; total quality management and learning organisation).
- Kreanet: network of academicians and consultants in the field of creative problem solving in the Netherlands and Belgium.
- Ikhaya (the Netherlands): specialists in knowledge management
- Unilever (The Netherlands): specialists in marketing and customers research

In the most of the cases the interview was conducted in a small groups (2-5) of people. The only exception was the discussion organised with people from the KreaNet. Thirty people were involved in the discussion. In two cases the interview was conducted individually.

8.2.3 Procedure

The expert focus group interviews were carried out in November – December 2000. The typical case of a focus group discussion included the following steps:

- Experts get an opportunity to look at the SMILE Maker Tool in advance. Specific instructions about the tool and how to navigate were sent to them. In some cases, if participants want, some papers describing the SMILE Maker Tool were attached to the package.
- A short presentation of the SMILE Maker Tool before the evaluation session is organised.
- Group discussion about the tool is conducted.

8.2.4 Results

The data were tape recorded, then scripts were made, and finally pattern coding and memoing were accomplished. The data were analysed looking for some common themes. A cognitive map was constructed to visualize the main points of the discussions (See Figure 42).

The outcomes of the experts' evaluation are presented within the following categories: 'general', 'the SMILE problem solving method', 'learning environment', 'interface', and technical.

8.2.4.1 General

- It was found that the SMILE Maker Tool proposes an interesting and challenging combination between problem solving and learning.
- The SMILE Maker Tool was defined as an individualized electronic book for creative problem solving.
- The generic methodology of the SMILE Maker Tool was welcomed but a suggestion was made for some more concrete realizations of the methodology taking into account the domain of application. An idea was launched for a number of small 'Smiles'.

8.2.4.2 SMILE Problem Solving Method

- Heuristics in procedures are helpful but from another side imposing a structure in the open space mode may interfere creative thinking.
- Supporting versatility of problem solving styles was described as a very powerful idea.
- The SMILE Problem Solving Method supports the process of problem solving but at the same time it might disturb problem solver to have to concentrate on the content of the problem. While emphasizing meta-level support, the SMILE Maker Tool may hinder support on subject matter level.
- The SMILE Problem Solving Method proposes many techniques for creative problem solving but they will be too much for an inexperienced user.

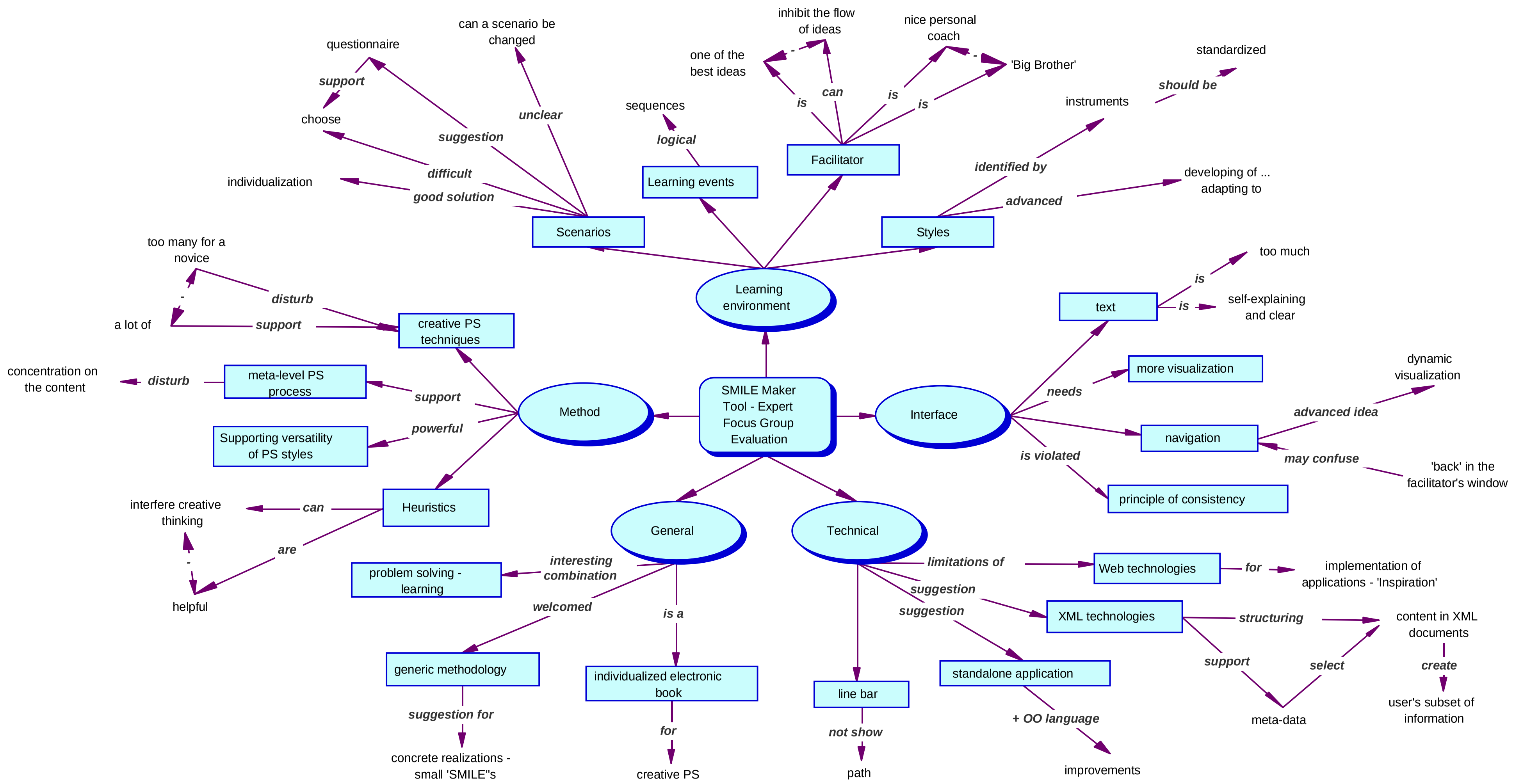


Figure 42. Expert focus groups' cognitive map

8.2.4.3 Learning environment

- Scenarios were found to be a good solution for the individualization of the instruction but it is difficult to make a choice which of them is the most appropriate. In the current version the selection of a scenario is like 'an expedition'. A suggestion is made for a support in identifying in advance the preferences to a particular scenario with a questionnaire – an approach similar to that of the Tailor-made scenario for identifying learning styles.
- It was not clear whether it is possible to change a scenario in the process of problem solving.
- The sequence of learning events was defined as quite logical.
- From one side the facilitator was defined as one of the best ideas in the SMILE Maker Tool, but from another it was blamed for inhibiting the flow of ideas of a problem solver. It is a very nice personal assistant but at the same time it is something as 'eyes over shoulder' or 'Big Brother'.
- All instruments for identifying the styles of users must be standardized. It is not the case with problem solving styles and learning locus of control in the current version of the SMILE Maker Tool.
- The idea of developing learning styles rather than only adapting to learning preferences was found as very advanced.

8.2.4.4 Interface

- From one side, the text was self-explaining and the explanations were clear, from another side, the text was too much. Suggestions were made for more visualization – maps, diagrams and graphics. More visualization is required to clarify the structure of the SMILE Maker Tool.
- There is violation of the principle of consistency. The view of each of the scenarios is different.
- It was said that navigation through dynamic visualization is very advanced idea but some problems were found in the navigation through Ready-made and Tailor made scenarios.
- The button 'back' in the facilitator's window may confuse the user who is used to the classical Windows view.

8.2.4.5 Technical

- While Web solutions were appropriate for the present time, it was argued that client-side Web technologies create some limitations especially in the implementation of some applications such as ‘Inspiration’. For example XML technologies are believed to be a better solution now. SMILE Maker Tool could be structured in XML documents accompanied by meta-data. Meta-data can be used to select the most appropriate subset of information for a particular user.
- Some improvements could be made if the tool is implemented as a standalone application written in a powerful object-oriented programming language.
- The line bar does not show the path to a particular source which is important for navigation.

Most of the statements were made not in a ‘black & white’ format. An ‘Either-or’ format suggests that a balance should be found between the two opposite sides.

8.3 General conclusions

This chapter was aimed at assessing the effectiveness of the SMILE Maker Tool. Two types of data collection method were applied: an experiment and expert focus group interviews. Respectively two types of data were collected: quantitative via the experiment and qualitative via the expert focus group interviews

From quantitative point of view the experiment measured the effects of the SMILE Maker on successful solution of a case, mapping production, and perceptions of people. Four factors have been identified that might contribute substantially to the power of the tool for solving design problems. These are knowledge elicitation, knowledge representation, knowledge reflection, and knowledge creation. The effectiveness of the SMILE Maker Tool is due to the explicit systematic support it provides for making active these factors.

The experiment provided some data about the learning environment of the tool. The effectiveness of the SMILE Maker as a learning tool is attributed to the individual approach it proposed. Students can select and follow a learning path that is a projection of their learning preferences. The individual approach is based on specific patterns of four learning events: explanation, examples, procedures and practice.

From qualitative point of view the expert focus group interviews made some valuable suggestions about the SMILE Maker. While emphasizing on the positive sides of a particular characteristic of the tool, the suggestions pointed out also the issues that may appear. For example, the SMILE Problem Solving Method is designed as a generic approach but it should be adapted for more concrete domain applications. The appearance of the facilitator while being useful for the users should not disturb their thinking. The availability of some creative problem solving techniques should not overwhelm the users.

Both the quantitative and qualitative data contributed to draw conclusions about three main features of the SMILE Maker tool: the SMILE problem solving method, the SMILE Maker learning environment and the interface of the tool. The positive points of convergence can be summarized as follows:

- The systematic approach for solving design problems that SMILE Maker provides.
- A framework consisting of four stages and deliverables: map information collection, map idea generation, and idea selection, and map idea implementation with possible loops between them.
- The idea of combining mental mapping approaches and creative problem solving techniques for developing the guidelines of the method.
- The idea of matching either explicitly or implicitly the instructional conditions to personal constructs of users.
- The idea that each sort of content could be presented with particular formats of four learning events: explanation, examples, procedures, and practice.
- The idea of identifying learning styles of people through the four learning events of explanation, examples, procedures and practice.
- The idea of developing versatility of the individual characteristics of people instead of just adapting to them.
- The idea of an electronic personal assistant, or coach which supports activities of a user and develop his or her personal characteristics.

The points of negative convergence could be formulated as follows:

- The problem solving approach of the SMILE Maker is too generic.
- The techniques for creative problem solving that the SMILE Maker offers are too much.
- The number of the appearances of the Facilitator should be reduced.
- The text presenting the method is too much.
- There should be a support for identifying the preferences to a type of learning scenario.

Chapter 9. Conclusions and recommendations

This chapter is aimed at drawing conclusions and making recommendations for improving the *SMILE Maker* as both problem solving and learning tool. The chapter reminds the issues of the educational and training design that raised the need for reconsidering the role of concept mapping in that process (Section 9.1). Then the approach applied in the study to deal with the issues is presented. (Section 9.2) based on three theoretical perspectives: problem solving (Section 9.2.1), mapping (Section 9.2.2) and learning (Section 9.2.3). Section 9.3 summarizes the main outcomes of the design and development of the SMILE Maker. Section 9.4 presents the results from the evaluation of the SMILE Maker tool.

9.1 The Issues

The objective of the current study is supporting the educational and training designers to improve their performance in ill-structured design situations applying a concept mapping technique. Two main issues were identified: one referred to the characteristics of the educational and training design process and another was attributed to the role of concept mapping in this process. In more concrete terms those issues can be formulated as follows:

- Existing educational and training design methodologies provide mainly a general framework for design activities. They a short in suggesting concrete operational procedures, guidelines, techniques and tool to shape the design activities in a most effective and efficient way.
- Concept mapping has a potential to improve the educational and training design process supporting the high cognitive level skills such as problem solving. However the technique was used mainly as a graphical advance organizer supporting relatively low cognitive levels. Traditionally, concept mapping was considered as a predominately knowledge representation technique. Its potential to be a power technique for knowledge elicitation, knowledge reflection, and knowledge creation was underestimated.
- The study points out the existence of some other mapping approaches in addition to concept mapping. The analysis of those mapping approaches shows that they have some valuable characteristics that might be beneficial for improving the design process.
- The study pays a special attention to the role of concept mapping software in the design process. It was reported that the great potential of concept mapping software in the design process was not used in its full extent. Concept mapping software was applied mainly as a drawing tool. Apart from that the analysis of the mapping software related to other

mapping approaches showed that no support is provided for the mapping methods they apply.

The approach that the current study applies to deal with the issues refers to designing and developing a tool that builds up a learning environment and provides a method supporting educational and training problem solving. The tool is called SMILE Maker.

9.2 The Approach

Three theoretical perspectives contribute to the constructing of the SMILE Maker: problem solving, mental mapping and learning. Problem solving and mapping contribute to developing a concrete method supporting design activities. Learning is considered as beneficial for developing an individualized learning environment. The three theoretical perspectives are going to be considered in more detail in the following sections 9.2.1 (Problem solving), 9.2.2 (Mapping), and 9.2.3 (Learning).

9.2.1 Problem solving

This study provided some answers to the research question ‘How problem solving paradigm contributes to development of the SMILE method?’ The theory and practice of the design methodologies in the most of the engineering disciplines and business management show that problem solving paradigm is used largely for developing of concrete operational methodologies in these domains. The educational and training design is as process of solving design problems, most of which are ill structured. The problem solving paradigm contributes to the design of the *SMILE* method with the following ideas:

- Solving educational and training problems should be considered in systematic terms as a process consisting of several stages, which have specific purposes. These stages are information collection, idea generation, idea selection and solution implementation with possible loops between them.
- In each of the stages both divergent and convergent activities are needed. Divergent activities are organized for broadening the perception on the issue. Convergent activities narrow the scope of the search, organizing and selecting ideas. Usually each stage begins with some specific divergent activities, before turning to some convergent activities.
- Some creative problem solving techniques are applied to provide a specific support to the activities in each of the stages of problem solving. Apart from that the rules of brainstorming, creative problem solving principles, and the integrative potential of some problem solving methodologies are valuable ideas as well as that could be taken into consideration when designing a method for solving ill-structured design problems.

- Supporting knowledge elicitation, knowledge reflection, knowledge representation and knowledge creation applying creative problem solving principles and techniques.
- Identifying problem solving styles as the individual preference people have in organizing information. Problem solving styles are defined as the extent to which people have strong preferences to one of the activities on the general problem solving cycle - information collection, idea generation, idea selection and idea implementation. The four types of problem solving styles that are identified for the purposes of the current study are seeker (strong in information collection), diverger (strong in idea generation), converger (strong in idea selection), and doer (strong in idea implementation).
- The existence of negative problem solving syndromes, mental blocks and barriers that impede the effectiveness of problem solving. Knowing what they are might help in assigning some relevant interventions for overcoming their negative effects.
- The role of cultural artefacts in overcoming the limitations of human information processing. Artefacts manage the complexity instead of reducing complexity in problem solving. Mental maps are believed to have the characteristics of artefacts.

9.2.2 Mapping

The study investigated the research question of how different mapping approaches contribute to the development of the SMILE problem solving method. Different mapping approaches have been analysed in relation to their theoretical framework, procedures and software. While being based on different theories those mapping approaches share some common characteristics. These are as follows:

- All mapping approaches apply map as an explicit metaphor to show the relationships between the components of human cognitive and affective structures.
- Mental maps are described as the most adequate, practical, flexible, and accurate model of expressing the way our mind receives, stores, organises, represent and change information.
- Mental maps mirror human cognitive and affective structures.
- The close correspondence between cognitive structures and their external modes of representation through mental maps speeds up the retrieval of information.
- Mental maps could represent the whole picture of problem solving space and the relationships between its components.

- Mental maps are concise, compact, and parsimonious, but at the same time they are very rich of information. Maps integrate two kinds of coding - verbal and visual. They capitalise on the advantages of graphical representations without losing the flexibility and the power of natural language system.
- Mental maps allow reflection on and analysis of mental patterns about a particular problem solving situation and investigation of the relationships and configurations between components of this pattern.
- Mental maps and especially mapping software allow problem-solving representations to be manipulated in order to discover different perspectives and exploring new possibilities.
- A mental map is an external extension of working memory, reducing the cognitive overload in complex problem situations.

All those specific characteristics make mental maps quite powerful techniques for knowledge elicitation, knowledge reflection, knowledge representation, and knowledge creation.

9.2.3 Learning

The research question related to the concept of learning is how the varieties of learning and instructional design approaches contributed to designing of an individualized learning in the *SMILE Maker* tool. Learning paradigm brings to the table the following ideas:

- The need of establishing a striking balances between constructivism and instructivism educational philosophies and between content-by-treatment and aptitude-by-treatment instructional design approaches.
- The existence of a large number and multi-layers individual constructs that are unstable over time space and task.
- A pattern was derived out from the analysis of different instructional design theories and approaches. The pattern consists of the following learning events: explanation, examples, procedures and practice. They could be considered as stages of the general learning cycle. Learning can start anywhere on this cycle. Learning events are a good basis for defining learning styles as people develop different degree of preferences to one or another learning event.
- The idea of matching the instructional conditions through accommodation of learning styles.
- The idea of development learning styles rather than just adaptation to learning preferences.

All the ideas discussed above were applied as design solutions in the *SMILE Maker* – a web based learning environment supporting problem solving.

9.3 The SMILE Maker Tool

The research question reflecting the design issues of the *SMILE Maker* is ‘What are the design solutions and how they were implemented in the SMILE Maker?’ The main outcomes in searching for answers of this question are listed as follows:

- SMILE is based on a model consisting of four main components: method, learning events, user and facilitator. The method is a consolidation between the advantages of different mapping approaches and creative problem solving. It consists of four types of maps: information collection map, idea generation map, idea selection map, and idea implementation map. Each of them has a particular purpose and applies some specific creative problem solving techniques. There are four learning events: explanation, examples, procedures and practice. The abstract notion of user has four characteristics: learning styles, learning locus of control, problem solving styles and level of prior knowledge. Facilitator is entity that suggests to a user a particular behaviour based on specific rules. It has four faces: advisor, navigator, profiler and system helper.
- The main parts of the model are implemented in four learning scenarios. They are ready-made, tailor-made, self-made and atelier. Each of them offers specific configuration of the components of the method and learning events. Learning scenarios are the most operational mechanism of the SMILE learning environment. They provide opportunities for individualization of the instruction according to learning styles, learning locus of control, problem solving styles and levels of prior knowledge.

The quality of the design solutions in the *SMILE Maker* was evaluated in two experimental researches and several focus groups interviews.

9.4 Evaluation of the SMILE Maker

There are two research questions reflecting the evaluation issues of the SMILE Maker. The first one is related to the performance effectiveness of the SMILE problem solving method. The second one is related to the performance effectiveness of the *SMILE Maker* tool.

The evaluation of *SMILE Maker* includes different phases in which both quantitative and qualitative methods were used within the methodological framework of the concept of research triangulation. The effectiveness of the SMILE method was measured against the performance on a case as a result and maps production as a process of applying the method. In order to show whether the SMILE method could be effective in a process of solving educational and training design problems an experiment was organized involving two groups. One group solved a case using the classical concept mapping approach and another group applied the SMILE method. The data revealed that the group of SMILE demonstrated significantly better results in solving the case. The analysis of mapping production show that the SMILE method is significantly better in the broadness and deepness of representing the problem situation, the number and the originality of ideas generated for solving the case, the explicit and solid base for selecting the most appropriate solution, and in the predicting factors that might affect the implementation of solution and drawing a plan for putting the solution into practice.

The effectiveness of the *SMILE Maker* tool was evaluated in another experiment through scores on solving a case, map production and personal reflections against the same indicators when the *Mind Manager* is used. According to the data of the second experiment the method that *SMILE Maker* implements is significantly better in solving an ill structured case. This is because the perception on the problem situation is broader and deeper, the idea generation is more productive, the selection of the most appropriate solution is more reliable, and the implementation of the solution is more feasible. The higher are results of mapping production the better is performance on the case. Apart from that there is a strong positive correlation between the components of the map production. For instance, the quality of idea generation depends on the quality of information collection. The probability to select a good solution among generated alternatives is higher if the quantity of idea generation is high. The implementation of the solution is dependent on the quality of the activities in all previous stages. The implementation of the solution is related very much to the identification of the important factors done during of information collection. The selection of the most appropriate candidate among solutions generated is affected by the predictions about solution implementation.

During the focus group interviews a good reception got the ideas of the SMILE systematic approach, looping between stages, creative problem solving techniques based on mapping, and developing the problem solving styles of users. Some suggestions are formulated for improving the method. For example, it seems that the method being so generic needs some concrete realizations depending on the domain, context, task and the target group. The language is too instructive and the structure imposed on the content should be more flexible. Some more explicit recommendations should be attached to the techniques - which of them in what circumstances is appropriate to be used.

There is a direct strong positive relationship between the successful application of the SMILE method and the opportunities for studying the method. The way learning environment of

SMILE Maker is organized proves to be a substantial factor in successful application of the problem solving method. The reflections on the process of using *SMILE Maker* and the focus group interviews with experts show the positive attitudes to the idea of individualization of instruction through the four learning scenarios and different configurations of the four learning events within each of the scenarios. Users like to have an explicit and individualized support for studying the SMILE method. Developing learning styles instead of adapting to learning preferences was noticed especially as very promising idea worth to elaborate further on it. The recommendations about the learning environment of the *SMILE Maker* were in the direction of more explicit support in identifying the type of learning scenario and the possibility to change already selected scenario. According to the evaluation of the *SMILE Maker*, the facilitator is a useful function for developing learning and problem solving styles but further thinking is needed for the improvement of its appearance on the screen.

The users were not impressed very much from the interface solutions of the *SMILE Maker* although the positive reactions were more than expected. The users of the *SMILE Maker* reported some difficulties in navigation through the ready-made and tailor-made scenarios because of lot of text. However they admitted that *TheBrain* navigation window was very useful for knowing where you are in the site when browsing. Some recommendations were made in relation to the visualization of the site. According to the experts a sort of concept or mind map would be a good solution against the text which overwhelm the users, especially in ready-made scenario.

This chapter so far summarized the outcomes of the study. Some interpretations of the research data were reported. The following section 9.4.1 'The SMILE Maker as a problem solving tool' will discuss why *SMILE Maker* might be considered as a useful tool for solving educational and training design problems. This section will recall some the ideas presented in the section 8.1.6 'Discussion' of chapter 8.

9.4.1 The SMILE Maker as problem solving tool

SMILE Maker provides with a systematic approach for solving educational and training design problems. Systematic means a set of stages with specific purposes, techniques and deliverables. The problem solving method consists of four stages: information collection, idea generation, idea selection and idea implementation. Each of them requires a particular deliverable – map information collection, map idea generation, map idea selection and map idea implementation. The systematic approach supports overcoming some of the common negative problem solving syndromes such as analysis-paralysis, premature closure, and functional fixedness, which characterize the one-side development of problem solving styles.

Because of different reasons people develop preferences to one of the problem solving activities (information collection, idea generation, idea selection and idea implementation). The requirements to go through the stages of the SMILE problem solving method may compensate the week part of problem solving abilities of people. For example people with an inclination in idea selection will get a support for developing their capacity in information collection, idea generation and idea implementation. SMILE problem solving method support development of a complex and versatile problem solving style.

SMILE Maker problem-solving method begins with some divergent activities for collecting information. The purpose is to elicit all available knowledge about problem situation. The knowledge items might be facts, statistics, feelings, metaphors, etc. What happens is a sort of visual brainstorming with some techniques added such as ‘Free association’, ‘Six Universal Questions’, ‘Ask Five Times Why’, and ‘Consider All Factor’. *SMILE Maker* supports the broad and deep exploration of the problem situation and building a relevant mental model of this situation. It is possible that during the reflection on map information collection some solutions to be formulated even in this relatively early stage.

The *SMILE Maker* problem solving method stimulates the generation of as many as possible alternatives. It offers a set of techniques that force breaking down the dominant thinking pattern and creating original and unconventional solutions. The problem solving method that the SMILE Maker implements proposes four techniques for idea generation: ‘scratch’, ‘pairs’, ‘change labelling’, and ‘’hot spot’. They are modification of some creative problem solving techniques (attribute listing, morphological analysis, analogies, metaphors, free association, and brainwriting) taking into account the characteristics of mapping. For example the ‘scratch’ techniques is a free association based on the items in map information collection. ‘Pairs’ is a deliberate combination between some ‘objective’ (facts, statistics) and some ‘subjective’ (feelings, metaphors) type of knowledge items to provoke creating something meaningful that is also original. ‘Hot spot’ is based on another characteristic of mental maps. It stimulates the purposeful reconfiguration of the map as putting one of the marginal nodes in the centre of the map. ‘Change labelling’ also explores a characteristic of the mental maps – labels on the links between nodes. The creative problem solving principles and techniques together with the mapping format help in reflecting-in the process of eliciting and representing problem solving thinking patterns in order to create original solutions.

The same processes of eliciting, representing, reflecting and creating are involved in idea selection stage but serving different objectives. The brainstorming principles and free association support elicitation of a set of criteria for selecting the most appropriate solution candidate. Then a knowledge representation technique such as a weighted matrix comes to support the convergence on the best solution candidate. A problem solver could reflect on the matrix checking each of the alternatives against the set of criteria in order to make his or her mind.

Solution implementation starts with eliciting and representing all positive and negative factors that are supposed to play an important role in the implementation of the solution. Then a set of preventive (to the negative factors) and supportive (to the positive factors) actions are elicited and represented. Reflection on that picture leads to creation of a plan for implementation of the solution.

The data analysis revealed that the effectiveness of the *SMILE Maker* tool is due to an operational mechanism consisting of four characteristics known as knowledge elicitation, knowledge representation, knowledge reflection and knowledge creation. These functions exist in each of the stages of the method but aimed at different targets. They are not ordered in a linear format one after another. Eliciting is very much related to representing. Reflecting is based on the process and results of eliciting and representing and leads to creating. The *SMILE Maker* is a powerful problem solving tool because it supports explicitly all of the functions presented above applying a synergy between problem solving techniques and mapping. There are at least two main difficulties that problem solvers may experience in ill-structured problem situations: an access to the deep cognitive and affective structure, search and retrieval of the appropriate knowledge for solving the case, and the cognitive overload. Both types of difficulties are due to the characteristics of ill-structured problem situations.

The most of the educational and training problems are ill structured. The information is very complex, vague and incomplete. The procedures for solving these sorts of problems are unknown. There is not an agreement upon the right solution. A problem solver has to find the appropriate knowledge and to match this knowledge to the external stimuli of a problem situation. These processes occur in the working memory, which has a limited potential. Because of this most of the people, including experts, struggle to deal with such kind of problem situations. People deliberately try to reduce the complexity of the situation taking the first solution that come to their mind if it sounds satisfactory. Usually they apply the dominant thinking pattern as it appears at the moment. However, in the most of the cases it is not the best solution.

Problem solving principles and techniques from one side and the specifics of mapping representation from another facilitate searching and retrieving deeply in the cognitive and affective structure for appropriate knowledge in an open ended problem situation. Thus, the SMILE problem solving method supports eliciting the knowledge needed for solving a problem. The SMILE method visualizes the process of knowledge eliciting through drawing a map as the most relevant and intuitive external mode of representation of the mental models of problem situations. Applying the simple format of mapping a problem solver can represent very complex models. The SMILE method encourages elicitation of different types of problem solving representations such as facts, statistics, feelings, analogies and metaphors. They are linked in a network through descriptive, causal, structural, and metaphorical relationships. Exploring a problem situation in a map format allows managing the complexity of the situation and reducing the cognitive overload. The visualization of the internal thinking model in a map format is a kind of working memory aid. The externalisation of the problem spaces frees-up the working memory. Knowledge eliciting and representing call for reflecting on the problem solving mental model. That leads to creating of a new knowledge if a relevant support is organized.

The *SMILE Maker* tool applies ‘Inspiration’ as mapping software tool. ‘Inspiration’ has several functions that could support knowledge elicitation. This tool is very expressive for knowledge representation as well. ‘Inspiration’ can represent any kind of information items and any kind of relationships between them. During the reflection on map structure, ‘Inspiration’ allows easy moving the nodes from one place to another and making clusters, thus leading to reshaping problem solving space and provoking creation of new ideas.

Apart from problem solving tool, the SMILE Maker can be defined as a learning tool as well as. The next section 9.4.2 deals with this issue.

9.4.2 The SMILE Maker as a learning tool

As a learning tool the *SMILE Maker* offers an approach for studying the *SMILE Maker* problem solving method. The learning approach of the *SMILE Maker* tries to match the instructional conditions to the learning preferences of users. It individualizes the study according to users’ learning locus of control, learning styles and level of prior knowledge. The first major concept in the *SMILE Maker* as a learning tool is ‘learning scenario’. There are four learning scenarios: ready-made, tailor-made, self-made and atelier. Learning scenarios define the learning locus of control of users. The concept of learning locus of control distinguishes people on a continuum with two extremes: external learning locus of control and internal learning locus of control. Certainly there are some middle points. People with external locus of control prefer well-prescribed learning situations. People with internal locus of control prefer open-ended learning situation. The ready-made scenario is designed for people with external locus of control. The atelier scenario is designed for people with internal learning locus of control. Tailor-made and self-made scenarios take middle positions.

The second major concept in the *SMILE Maker* learning tool is ‘learning event’. Four learning events were identified as a pattern across different instructional approaches. The learning events are explanation, examples, procedures and practice. Explanation provides with some definitions and theoretical background. Examples might include also counter examples, simulations, and templates. Procedures are step-by-step guidelines toward achievement of a particular goal. Practice invites people to do the things. The four learning events can be recognised as stages on a general instructional cycle. Learning can start anywhere on this cycle. People developed preferences to one or another learning events thus defining their learning styles. The *SMILE Maker* identifies learning styles explicitly asking people to fill in a questionnaire or implicitly by selecting a learning event. For example, in the tailor-made scenario users of the *SMILE Maker* could identify their learning styles as filling in a questionnaire. In the self-made scenario they could select a learning event showing implicitly their learning preferences. The *SMILE Maker* study promoted the idea of developing learning styles of people instead of just adapting to their learning preferences. It means a special support is needed for developing the weak stylistic preferences. If, for instance, a person selects ‘examples’ learning event, he or she gets also some background information, procedures and invitation to practice.

The level of prior knowledge also can be matched as a user gets the opportunity to select what he or she needs. If a user is novice about the SMILE method he or she could select ready-made or tailor-made learning scenario depending on learning locus of control. If a user has some knowledge about the method already learned, he or she could select what exactly needs in self-made scenario. If a user is an expert in the domain of mapping or problem solving and like the idea of combining those two perspectives, then he or she will select atelier scenario.

Problem solving styles are defined as the preferences of people to one of the stages of the general problem solving cycle: information collection, idea generation, idea selection and idea implementation. According to that the problem solving styles identified for the purposes of the *SMILE Maker* study are seeker (strong in information collection), diverger (strong in idea generation), converger (strong in idea selection) and doer (strong in idea implementation). The idea of development versus adaptation is applied for the concept of problem solving styles as well. The problem solving styles can be detected implicitly according to the willingness of a user to follow a particular stage and to omit another.

In order to support people in developing their problem solving and learning styles a special function, called ‘facilitator’, was designed. It prompts some advises to the users in order to complete their learning and problem solving styles. ‘Facilitator’ follows the behaviour of a user and appears on the screen at a certain moment with some suggestions. Apart from the 'adviser' task, the facilitator has as well as profiler, navigator and system helper tasks. As a profiler it sends a user to a particular content pattern according to the dominant learning style. As navigator it shows to users where they are when browsing through the site. As a system helper the facilitator is supposed to provide some hints about downloading applications and saving the work.

As a prototype the *SMILE Maker* shows some promising features but it needs more work to be improved from technical point of view. The following section 9.4.3 comments on the technical issues of the current SMILE Maker implementation and possible future improvements.

9.4.3 Technical issues of the current SMILE Maker implementation and possible future improvements

In its current version the *SMILE Maker* is implemented as a web application that utilizes the most commonly used client-side web technologies. The content is encoded in HTML files and the dynamic aspect is programmed in JavaScript. These technologies bring a set of advantages and disadvantages.

The main benefit of using current web-based technologies is that the *SMILE Maker* is easily accessible and updateable. The requirements for the client side software are satisfied by any Java and JavaScript enabled browsers. This means that the current widely available browsers can run the application.

However, there is a number of disadvantages, which are mainly caused by the inherent features of HTML and JavaScript. HTML is a markup language with presentational semantics. It is intended to describe how data are rendered, while hiding the actual data structures. From the other hand, the content of the *SMILE Maker* conforms to a sophisticated information structure that describes the user's model and the correspondence between the content items and user models. HTML cannot represent this explicitly. JavaScript is a simple prototype-based scripting language without advanced object modelling capabilities. It is difficult to encode complex logic in that language.

The full potential of the *SMILE Maker* can be realized if the implementation is based on more powerful technologies. There are at least two possible directions for improvement:

- Usage of XML-related technologies. XML is a meta-framework, which allows creation of application specific markup languages. The main advantage over HTML is that a particular XML-based language can describe data structures with arbitrary complexity. As a consequence, the content of SMILE Maker can be structured in XML documents accompanied by meta-data. Meta-data can be used to select the most appropriate subset of information for a particular user. This reduces the complexity of adaptation algorithm. Unlike HTML, XML languages do not have presentational semantics. Presentation is specified in a separate structure called stylesheet. Different stylesheets can be provided for different target mediums, thus increasing the accessibility from currently unsupported platforms.

- Implementation as a standalone application.

Browsers impose some limitations on the applications running in their environments. The *SMILE Maker* requires fine control on the user interaction process and integration with external applications. These requirements cannot fully be met in the browser environment. Significant improvement can be made if the tool is implemented as a standalone application written in a powerful programming language. It might be Java or any object oriented language. This will result in achieving certain quality properties like robustness and adaptability.

English summary

This study investigates the role of specific graphical techniques that have become popular as 'mapping approaches' for solving complex design problems in the domain of education and training. These are concept mapping (Novak, 1998), cognitive mapping (Eden, Ackerman & Cropper), mind mapping (Buzan & Buzan, 1996), causal mapping (Vennix, 1997), hexagon mapping (Hodgson, 1999), and flowscape (De Bono, 1994). They are based on different theoretical backgrounds, offer different procedures and are implemented in different software packages but share some common fundamental characteristics. The most distinguished one is the mapping metaphor they apply. It means knowledge is presented in a spatial format where concepts are connected with labelled links to show the structure of problem solving space. The research in the domains of physiology and cognitive psychology has proved that mapping represents most adequately the way human mind organizes information. The close correspondence between internal processes and their external mode of representation make mental maps effective tools for thinking. Mental maps could overcome a fundamental weakness of the human processing system – the limited capacity of working memory. In fact, they extend the working memory making explicit the thinking models and patterns. Information retrieval is easier and reasoning becomes more effective and efficient. It leads to a reduced cognitive overload. However what was stated reflects the 'what-should-be' situation. In practice there is a gap between a 'what-should be' and a 'what is' situation of using mental maps for solving educational and training design problems.

Issues

The current project identifies some misperceptions about the role of mapping in solving design problems, which could be formulated as follows:

- Concept mapping is the only mapping technique.
- Concept mapping is a representation technique.
- Concept mapping just by the fact of its application produces good design ideas.
- Concept mapping software is only a graphical tool.

Concept mapping is only one of the existing mapping approaches. However, the current design methodologies for solving educational and training problems recommend only concept mapping and neglect *other mapping approaches* such as cognitive mapping, mind mapping, causal mapping, hexagon mapping and flowscape. They bring valuable ideas for improving the design process. For example, cognitive mapping could help in analysing complex problem solving situations. Causal mapping could identify the core issues. Mind mapping structures free association. Hexagon mapping facilitates some creative techniques such as visual brainstorming, force relationship, colour coding, and metaphors. Flowscape might be interesting with its lateral thinking methodological basis.

The traditional consideration of concept mapping defines the technique as a *representation* of specific predefined subject matter knowledge. It might be valid in instructional situations where learning objectives are related to remembering and understanding. *Concept mapping as a design technique supports problem solving which is a higher level in the learning taxonomy*. The representation functions of the technique in solving design problems serve different purposes than its representation functions in a simple learning situation. In design situations the representation functions of concept mapping support the analysis of the design situation, collection of information, generation of ideas, selection of the most appropriate one(s), and the implementation of the idea into practice. In addition to knowledge representation, concept mapping has a potential to be a knowledge elicitation, a knowledge reflection and a knowledge creation technique. These functions play an important role in situations where the goal is to design an educational or training product, but they have to be activated.

One of the myths around concept mapping is the believe that it can *bring in original design ideas just by the fact of applying the technique*. Concept mapping should be accompanied by explicit guidelines suggesting a systematic approach and providing with techniques that support information collection and analysis of design situation, idea generation, idea selection and idea implementation.

Mental mapping software should give a support not only to the graphical functions, but also to purposes, background and procedures of a specific mapping approach incorporated in it. The help systems of the existing mapping software tools support only the tools as graphical editors. They are a kind of information about what is and how to apply the method that is implemented in the software. Most of mapping software has a *potential* for knowledge eliciting, knowledge reflecting, knowledge creating and certainly for knowledge representing, while being strong in a particular function (s). For example ‘Decision Explorer’ – the cognitive mapping software, is particularly strong in knowledge reflection, but it has a potential for knowledge representation, and knowledge elicitation. ‘Inspiration’ – the concept mapping software is strong in knowledge representation, knowledge creation and knowledge elicitation but it also has a potential for knowledge reflection. The same is valid for ‘Mind Manager’. STELLA - a software tool supporting causal mapping is explicitly strong in knowledge representing and reflecting, but it has a potential for knowledge eliciting and creating. What is missing in all these software is a *relevant support to make the potential indeed operational*.

In addition to the misperceptions related to mental mapping approaches some issues related to the educational and training design methodology are detected. The most substantial is that the existing methodologies provide only a framework for design activities, but they are insufficient in offering concrete guidelines and techniques to facilitate the process of solving design problems.

Approach and results

In order to narrow the gap between the 'what-should-be' and 'what-is' situation and to improve solving design problems through mental mapping, the project sets as a goal to develop and evaluate the effectiveness of a tool that supports the design activities in this process. The tool is abbreviated as SMILE Maker and stands for Solution, Mapping, Interactive, Learning, and Environment. In more concrete terms it means an interactive learning environment for studying and applying a method based on mapping that supports solving design problems.

The design, development and evaluation of the SMILE Maker includes two main tasks:

- Designing developing and validating a method (here called the SMILE problem solving method) for solving design problems based on mapping and creative problem solving techniques.
- Designing, developing and evaluating a tool (here called the SMILE Maker Tool), implementing the problem solving method and providing with a structured learning approach for studying this method.

The SMILE problem solving method

Two theoretical perspectives interplay in designing the SMILE method. These are problem solving and mental mapping. Basically the process of solving educational and training problems is considered as a sub-set of ill-structured problem solving. The problem solving paradigm contributes to the SMILE method with the ideas of '*managing complexity'* instead of '*reducing complexity*', problem solving methodologies, stages of the problem solving process, creative problem solving theories, principles and techniques, and individual problem solving syndromes. The mental mapping paradigm contributes to the design of the SMILE method with the possibility for an externalisation of the variety of cognitive and affective structures, applying a simple graphical format combined with a verbal coding in order to recognize, elicit, represent, reflect, and create original and feasible design ideas. The mapping approach has a solid potential to reduce cognitive overload in solving ill-structured design problems. Mapping and problem solving are mutually amplifying each other in a task to support knowledge elicitation, reflection, representation and creation.

The SMILE method consists of four stages, namely map information collection, map idea generation, map idea selection and map idea implementation. It is an iterative process with moves ahead and back. In each of the stages a set of creative problem solving techniques is offered as both divergent and convergent activities are organized. The purpose of map information collection is to assemble all the available information concerning the problem under consideration. Map idea generation is aimed at producing as many solutions as possible. Map idea selection has to find the best candidate among the ideas. Map implementation is expected to propose a plan for making the selected solution workable in practice.

The evaluation of the SMILE problem solving method

The SMILE problem solving method was tested during two international workshops as qualitative data were collected from expert focus group interviews. The experts involved in the first workshop (Freiburg, Germany, 1998) expressed their positive opinions towards the systematic iterative approach including stages, and the variety of problem solving representations and links, showing the complexity of relationships between information items. They also were interested in using the creative problem solving techniques presented in each of the stages of the method. The experts made some recommendations in the direction for more background information about the method, and more examples. The second workshop (Sofia, Bulgaria, 1998) did not bring in ideas about the method itself, but challenged its theoretical background.

The SMILE method was also validated experimentally with groups of students. Using a factorial design the experiment investigated the effectiveness of the SMILE method against the Mind mapping method, analysing mapping production of the experimental and the control group after solving an ill-structured case. In addition to the 'method' as an independent variable with two levels (the SMILE and Mind Mapping), the second independent variable was 'learning style' (Doers and Thinkers). An interactive effect between the two independent variables was assumed. The data revealed that the experimental group using the SMILE method performed significantly better than the students in the control group on the main criteria of mapping production. The new method proved to be more effective in information collection, but especially in idea generation, idea selection and idea implementation. The SMILE method showed better results because it provides with an explicit support for knowledge eliciting, knowledge representing, knowledge reflecting and knowledge creating in each of the stages of the method. The SMILE problem solving method was incorporated in the SMILE Maker tool. No interaction effect was found between the two independent variables – 'problem solving method' and 'learning style'. This indicates that the SMILE problem solving method brings in a general beneficial effect along the different learning styles. It develops skills for all problem-solving activities.

The SMILE Maker tool

The process of designing and developing SMILE Maker tool is presented within the framework of the 3-Space Design Strategy (Moonen, 1999, 2000, 2001). It consists of three design spaces: consensus, task and implementation. The consensus space includes three activities: information collection, idea generation, and functional specification. The task space reports on the development and formative evaluation of a mock-up and the SMILE Maker prototype. The implementation space develops possibilities for a customisation of the tool.

The SMILE Maker is both a problem solving and a learning tool. As a problem solving tool it applies the SMILE problem solving method. As a learning tool it provides opportunities for studying the SMILE method according to the individual preferences of users. SMILE Maker as a learning tool matches learning styles, learning locus of control, problem solving styles and the level of prior knowledge of users. It identifies these personal constructs explicitly or implicitly. Users can fill in a special styles' inventory or they could simply select an options made available on the screen.

The SMILE Maker as a learning tool not only adapts but it also builds opportunities for developing individual preferences of users. The most operational options in the SMILE Maker as a learning tool are *scenarios*. They are particular patterns integrating the four units of the SMILE method and the four learning events of explanation, examples, procedures and practice. The four learning scenarios are *ready-made, tailor-made, self-made and atelier*. In ready-made scenario the four units (information collection map, idea generation map, idea selection map and idea implementation map) are presented within a sequence of the four learning events (explanation, examples, procedures and practice). The Tailor-made scenario gives users the opportunity to identify their learning style and according to that send them to content of the method matching their learning preferences. The Self-made scenario opens possibilities for users to select either a unit of the SMILE method or a learning event. The Atelier scenario invites advanced users to develop their own method for problem solving based on mapping and creative problem solving. This scenario provides external resources for problem solving, mapping, problem solving and mapping software, and templates. The learning environment of SMILE Maker proposes an option called 'facilitator' which plays an important role in developing versatile styles of users. The 'facilitator' has four functions: profiler, advisor, navigator, and system helper. As a profiler, the facilitator identifies, explicitly or implicitly, users according to their learning styles, problem-solving styles, learning locus of control, and level of prior knowledge. As a navigator, it gives an idea how to navigate throughout the site and dynamically shows where a user is at a particular moment.

As a system helper, the facilitator performs some routine functions on behalf of the system. The messages from the facilitator take the form of a pop-up window.

SMILE Maker is implemented as a web application. Its content is encoded in HTML files and the dynamic aspect is programmed in JavaScript. A supportive web site was developed to introduce to the theoretical background and the design model of SMILE Maker. The site applies a dynamic visual navigation mechanism based on the 'The Brain' technology.

The SMILE Maker evaluation

The methodology of the evaluation of SMILE Maker is based on the concept of triangulation. It means a combination between different research methodologies (quantitative and qualitative), target groups, data collection method, instruments, and data analysis techniques. An experiment was conducted to evaluate the effectiveness of SMILE Maker tool. It was compared with Mind Manager tool against a performance in solving a case, map production, and the perception of the experimental subjects about the method, learning environment and the interface of the tools. In addition to the experiment different profile experts took part in series of focus group interviews. The experimental data show that the usera of SMILE Maker are superior in solving an ill structured case, performed significantly better on the main criteria of map production and got higher scores on the items of the reflective questionnaire. The effectiveness of SMILE Maker is attributed to the explicit systematic support for making operational the functions of knowledge eliciting, knowledge reflecting, knowledge representing and knowledge creating. The effectiveness of SMILE Maker as a learning tool is due to the individual approach it provides. Students can select and follow learning paths that reflect their learning preferences.

The expert focus group interviews bring in some valuable suggestions about SMILE Maker as a problem solving tool and as a learning tool. For example, the SMILE problem solving method designed as a generic approach should develop more concrete domain applications. The appearance of the facilitator while being useful for the users should not disturb their thinking. The availability of some creative problem solving techniques should not overwhelm the users.

SMILE Maker should be consider as a prototype for testing some ideas of improving the process of solving design problems. The evaluation of the prototype proved that SMILE Maker is an effective problem solving and learning tool. However there is a lot of room for improving the problem solving method, learning approach and especially the interface. The current project focuses on the SMILE Maker as an individual tool. A promising perspective is to design, develop and evaluate the SMILE Maker as tool for supporting group activities.

Samenvatting

Dit onderzoek onderzoekt de rol van specifieke grafische technieken die bekend zijn geworden als varianten van 'concept mapping', bedoeld om complexe ontwerpproblemen mee op te lossen op het gebied van onderwijs en training. Deze varianten zijn: Concept mapping (Novak, 1998), cognitive mapping (Eden, Ackerman & Cropper), mind mapping (Buzan & Buzan, 1996) causal mapping (Vennix, 1997), hexagon mapping (Hodgson, 1999) en flowscape (De Bono, 1994). Zij zijn op verschillende theoretische achtergronden gebaseerd. Zij bieden verschillende procedures aan en zijn in verschillende software geïmplementeerd, echter ze hebben fundamentele eigenschappen gemeen. Wat het meest opvalt is de mapping metafoor. Deze houdt in dat kennis in de ruimte wordt afgebeeld, waarbij begrippen van gelabelde relaties zijn voorzien. Hiermee wordt de structuur van de probleemruimte zichtbaar. Het onderzoek naar de gebieden fysiologie en cognitieve psychologie heeft uitgewezen dat de begripsnetwerken dichtbij de manier staan waarop mensen informatie in zich opnemen. De nauwe overeenkomst tussen interne processen en hun externe afbeelding maken concept maps tot geschikte denkgereedschappen. Concept maps kunnen in principe de inherente zwakte van het menselijke brein compenseren - de beperkte capaciteit van het werkgeheugen. In feite vormt de concept map een uitbreiding van het werkgeheugen, waarbij ze de denkmodellen en -patronen expliciet maakt. Het terugzoeken van informatie is gemakkelijker en het redeneren gaat beter en efficiënter. Het kan leiden tot minder cognitieve last. Tot zover over hoe het 'zou moeten gaan'. In de praktijk is er een kloof tussen de gewenste en de daadwerkelijke situatie rondom het gebruik van concept maps bij het oplossen van onderwijskundige- en trainingsproblemen.

Onderwerpen

Het onderhavige onderzoek is op zoek naar mispercepties over de rol van concept mapping bij het leren probleemoplossen. Ze kunnen als volgt geformuleerd worden:

- Concept mapping is de enige mapping methode
- Concept mapping is een representatietechniek
- Concept mapping garandeert zonder meer dat er goede ontwerpideeën ontstaan
- Concept mapping is alleen een grafisch gereedschap

Concept mapping is slechts een van de bestaande mapping benaderingen. Echter de huidige ontwerpmethoden voor het oplossen van onderwijs- en trainingsproblemen gaan alleen maar in de richting van concept mapping; zij gaan vaak voorbij aan *andere mapping methoden* zoals cognitive mapping, mind mapping, het mappen van causale ketens, hexagon mapping en flowscape. Deze kunnen waardevolle ideeën inbrengen voor het oplossen van ontwerpproblemen. Zo kan cognitive mapping helpen bij het analyseren van complexe probleemcontexten. Causale ketens kunnen de kernproblemen helpen identificeren. Mind mapping ondersteunt op haar beurt het proces van vrije associatie. Hexagon mapping bevordert sommige creatieve technieken zoals visuele brainstorming, het afdwingen van relatietypering, kleurcodering en metaforen. Flowscaping kan interessant zijn in combinatie met de methodische basis van lateraal denken.

De traditionele opvatting over concept mapping definieert de techniek als de *neerslag* van een specifiek kennisgebied. Dit past in instructiesituaties waar leerdoelen gekoppeld zijn aan het zich herinneren en het begrijpen. *Concept mapping als een ontwerptechniek legt de nadruk op probleemoplossen hetgeen thuishoort op de hogere treden van de leerhiërarchie*. De representatiefuncties van de techniek bij het probleemoplossen dienen andere doelen dan de representatiefuncties in een simpele leersituatie. Tijdens het ontwerpen helpen de representaties de analyse van de ontwerpsituaties, de verzameling van informatie, het genereren van ideeën, het selecteren van de beste ideeën en het implementeren van een idee in de praktijk. Als toevoeging op kennisrepresentatie heeft concept mapping de mogelijkheid om kennis uit te lokken, te bespiegelen en kennis te genereren. Deze functies spelen een belangrijke rol in situaties waarin het doel is om een educatief of trainingsproduct te ontwerpen; echter zij moeten wel geactiveerd worden.
Een van de mythes rondom concept mapping is de overtuiging dat het nieuwe ontwerpideeën kan *aandragen door simpelweg de techniek toe te passen*. Concept mapping moet begeleid worden door expliciete richtlijnen en een systematische handelwijze te volgen en gebruik te maken van technieken die specifiek bedoeld zijn voor informatieverzameling, de analyse van de ontwerpsetting, idee genereren, idee selectie en idee implementatie.

Software voor het afbeelden van gedachten moet niet alleen grafische functies hebben, maar ook doelen, achtergronden en specifieke zienswijzen op mapping vertegenwoordigen. De helpsystemen van bestaande mapping software tools gaan vrijwel alleen in op de grafische editors. Zij zijn van het type software dat alleen ingaat op die ene manier van bouwen zoals door de ontwerper van de software bedacht is.

De meeste mapping software is *in principe* in staat om een speciaal soort kennisoperatie uit te voeren. Zo is 'Decision Explorer' opvallend sterk in kennisbespiegeling, maar het heeft ook een zeker vermogen tot kennisrepresentatie en kennisuitlokking. 'Inspiration' blinkt uit in representatie, creatie en uitlokking, maar is potentieel sterk in kennisreflectie. Hetzelfde geldt voor 'Mind Manager'. STELLA: een softwarepakket voor de ondersteuning van causaal redeneren is opvallend sterk in kennisrepresentatie en reflectie, maar het heeft een nevenpotentieel voor uitlokking en creatie. In al deze software missen we *support om het idee om te zetten naar de realiteit.*

In aanvulling op de misvattingen aangaande mentale maps wordt er ook specifiek ingegaan op ontwerpmethoden voor onderwijs en training. Het meest duidelijk is dat de bestaande methoden alleen voorzien in een kader voor ontwerpactiviteiten, maar nauwelijks in het aanbieden van concrete richtlijnen en technieken om het probleemoplossingsproces zelf te ondersteunen.

Aanpak en resultaten

Om de kloof tussen de gewenste en de aanwezige situatie te verkleinen, en om het oplossen van ontwerpproblemen door mentale maps te optimaliseren, stelt het project tot doel om een specifiek softwaregereedschap te ontwikkelen en te evalueren, zodanig dat dit de ontwerpactiviteiten ten goede komt. Het softwaregereedschap wordt kortweg SMILE Maker genoemd en staat voor Solution, Mapping, Interactive, Learning en Environment. Meer concreet betekent het een interactieve omgeving voor het bestuderen en toepassen van een methode die gebaseerd is op concept mapping en gericht is op het oplossen van ontwerpproblemen.

Het ontwerpen, ontwikkelen en evalueren van SMILE Maker omvat twee hoofdtaken:

- Het ontwerpen, ontwikkelen en valideren van een methode (hier de SMILE probleemoplossingsmethode genoemd) voor het oplossen van ontwerpproblemen met betrekking tot mapping en creatieve technieken voor probleemoplossen.
- Het ontwerpen, ontwikkelen en evalueren van een gereedschap (verder de SMILE Maker Tool genoemd), waarmee de probleemoplossingsmethode wordt vormgegeven en die voorziet in een gestructureerde leeraanpak om die methode je eigen te maken.

De SMILE probleemoplossingsmethode

Twee theoretische perspectieven spelen een rol bij het ontwerpen van de SMILE methode. Deze zijn probleemoplossen en mental mapping. In essentie wordt het oplossingproces van educatieve en trainingsproblemen beschouwd als een variant van het oplossen van slechtgestructureerde problemen. Het probleemoplossingsparadigma draagt bij aan de SMILE methode met de ideeën van het '*beheersen van complexiteit*' in plaats van het *'reduceren van complexiteit*'. Daarnaast spelen probleemoplossingsmethoden, stadia in het oplossingtraject, creatieve oplossingtheorieën, principes en technieken en individuele oplossingssyndromen een rol. Het mentale mapping paradigma draagt bij aan het ontwerp van de SMILE methode met de mogelijkheid voor de externalisatie van de veelheid in cognitieve en affectieve structuren. Hierbij wordt een simpel grafisch formaat gecombineerd met een verbale codering. Dit teneinde het herkennen, uitlokken, representeren, weergeven en het creëren van originele en haalbare ideeën. De mapping benadering levert een stevige bijdrage om cognitieve belasting terug te brengen tijdens het oplossen van slecht gestructureerde problemen. Mapping en probleemoplossen zijn wederzijds versterkend bij taken zoals het uitlokken van kennis, het reflecteren, representeren en kenniscreatie. De SMILE methode omvat vier stadia: het verzamelen van map informatie, het genereren van ideeën voor de map, en het selecteren en implementeren van de map ideeën. Dit is een iteratief proces met stappen voor- en achterwaarts. In elk van de stadia wordt een set creatieve probleemoplossingstechnieken aangeboden met daarin convergente en divergente activiteiten. Het doel van de map informatieverzameling is om alle beschikbare informatie betreffende het probleem onder ogen te krijgen. De map selectie moet de beste kandidaat onder de ideeën uitzoeken. Van de map-implementatie wordt verwacht een plan voor te stellen, om de gekozen oplossing in de praktijk te laten werken.

De evaluatie van de SMILE probleemoplossingsmethode

De SMILE probleemoplossingsmethode werd getest gedurende twee internationale workshops waar kwalitatieve data werden verzameld uit expert focus groepen. De experts die betrokken waren in de eerste workshop (Freiburg, Duitsland, 1998) zeiden dat ze te spreken waren over de systematische iteratieve benadering. Ook waren ze te spreken over de variëteit van probleemoplossingsrepresentatie en de links die de complexiteit van de relaties tussen de informatie-items lieten zien. Ze waren ook geïnteresseerd in het gebruik van de creatieve oplossingstechnieken die in elk van de stadia werden gepresenteerd. De experts maakten enkele aanbevelingen in de richting van meer achtergrondinformatie over de methode en meer voorbeelden. De tweede workshop (Sofia, Bulgarije, 1998) bracht geen ideeën over de methode zelf. Wel werd de theoretische achtergrond ter discussie gesteld.

De SMILE methode werd ook experimenteel beproefd met groepen studenten. Gebruikmakend van een factorieel design onderzocht het experiment de effectiviteit van de SMILE methode ten opzichte van de Mind Mapping methode. Hierbij werd de productie van de maps geanalyseerd van de experimentele- en de controlegroep nadat een slecht gestructureerd probleem was opgelost. Vervolgens werd aan de 'methode' als onafhankelijke variabele met twee waarden (de SMILE versus de Mind Mapping methode) de tweede onafhankelijke variabele 'learning style' (doeners versus denkers) toegevoegd. Er werd een interactie-effect tussen de twee onafhankelijke variabelen verwacht. De data wezen uit dat de experimentele groep die de SMILE methode had gebruikt beduidend beter scoorde dan de studenten in de controlegroep ten aanzien van het criterium van map productie. De nieuwe methode bleek meer effectief bij informatieverzameling maar vooral bij het genereren, selecteren en implementeren van ideeën. De SMILE probleemoplossingsmethode toonde betere resultaten omdat ze voorzag in expliciete ondersteuning voor uitlokking, representatie, reflectie en de creatie van kennis tijdens elk van de stadia in de methode. De SMILE probleemoplossingsmethode geeft een algemeen positief effect bij elk van de leerstijlen; zij ontwikkelt vaardigheden voor alle onderkende probleemoplossingsactiviteiten.

Het SMILE Maker programma

Het proces van het ontwerpen en ontwikkelen van SMILE Maker wordt ondergebracht in het kader van de 3-Space Design Strategy (Moonen, 1999, 2000, 2001). Het omvat drie ontwerpruimten: consensus, taak en implementatie. De consensusruimte omvat weer drie activiteiten: informatie verzameling, idee genereren en functionele specificatie. De taakruimte rapporteert over de het ontwikkelen en over de formatieve evaluatie van een mock-up en het SMILE Maker prototype. De implementatieruimte ontwikkelt mogelijkheden voor het op maat maken van de tool.

SMILE Maker is zowel een probleemoplossings- als een leergereedschap. Als probleemoplossingsgereedschap past het de SMILE probleemoplossingsmethode toe. Als leergereedschap voorziet het in studiemogelijkheden voor het verkennen van de SMILE methode al naar gelang de individuele gebruiker daar behoefte aan heeft. SMILE Maker als leergereedschap stemt af op leerstijl, de locus of control t.a.v. het leren, probleemoplossingsstijlen en het niveau van voorkennis bij de gebruikers. Het stelt deze persoonlijk eigenschappen impliciet of expliciet vast. Gebruikers kunnen dit op een speciaal formulier invullen of zij kunnen eenvoudig een optie via het scherm kenbaar maken.

SMILE Maker als leergereedschap past zich niet alleen aan maar het voorziet ook in mogelijkheden om individuele voorkeuren van de gebruikers verder te ontwikkelen. De meest operationele opties in SMILE Maker als leergereedschap zijn de scenario's. Dit zijn bepaalde patronen die de vier units van de SMILE methode integreren met de vier leervormen: uitleg, voorbeelden, procedures en oefening. De vier leerscenario's zijn: *ready-made, tailor-made, self-made en atelier*. In het ready-made scenario worden de vier units (information collection, idea generation, idea selection en idea implementation) gepresenteerd in een reeks van vier leervormen (uitleg, voorbeelden, procedures en oefening). Het tailor-made scenario geeft de gebruikers de gelegenheid om hun leerstijl te onderkennen en dientengevolge worden ze naar de inhoud geloodst die geacht wordt aan te sluiten bij hun voorkeur voor leren. Self-made scenario opent de mogelijkheid voor gebruikers om of een unit uit de SMILE methode te kiezen of een leervorm te kiezen. Het atelier scenario nodigt gevorderde gebruikers uit om hun eigen methode voor probleemoplossen gebaseerd op mapping en creatief probleemoplossen te ontwikkelen. Dit scenario voorziet in extra benodigdheden voor probleemoplossen, mapping, mapping software en sjablonen. De leeromgeving van SMILE Maker toont een optie 'facilitator' genoemd die een belangrijke rol speelt in de ontwikkeling van flexibele stijlen bij de gebruikers. De facilitator heeft vier functies: profiler, adviseur, navigator en systeemhulp. Als een profiler herkent de facilitator (im- of expliciet) gebruikers aan hun leer- en probleemoplossingsstijl, locus of control, en hun niveau van voorkennis. Als navigator geeft het een idee hoe door de site te reizen. Ook toont het op dynamische wijze waar een gebruiker op een bepaald moment is. Als systeemhulp voert de facilitator routinefuncties uit ten gunste van het systeem. De berichten van de facilitator nemen de vorm aan van een pop-up venster.

SMILE Maker is gebouwd als web applicatie. De inhoud is in HTML files vastgelegd en de dynamische eigenschappen zijn geprogrammeerd in JavaScript. Er werd een begeleidende web site ontwikkeld om de theoretische achtergrond en het ontwerpmodel van SMILE Maker te introduceren. De site maakt gebruik van dynamische visuele navigatie, gebaseerd op de 'The Brain' technologie.

De evaluatie van SMILE Maker

De evaluatiemethode bij SMILE Maker is gebaseerd op het principe van triangulatie. Het betekent een combinatie van verschillende onderzoeksmethoden (kwantitatieve en kwalitatieve), doelgroepen, methode voor dataverzameling, instrumenten en data-analyse technieken. Er werd een experiment opgezet om de effectiviteit van de SMILE Maker tool te vergelijken met Mind Manager op het vlak van de performance bij het oplossen van een casus, de map productie en de waarnemingen door de proefpersonen van de methode, de leeromgeving en het interface van de programma's. Naast het experiment namen verscheidene experts deel aan een serie van focus groep interviews. De experimentele gegevens laten zien dat de gebruikers van SMILE Maker beter het ongestructureerde probleem oplossen, beter voldoen aan de criteria van de map productie en hogere scores behalen op de items van de reflectie vragenlijst. De effectiviteit van SMILE Maker wordt toegeschreven aan de expliciete systematische ondersteuning bij het operationeel maken van de functies voor kennisuitlokking, reflectie, representatie en het creëren van kennis. De effectiviteit van SMILE Maker als leergereedschap is onderhavig aan de individuele benadering die er uit voortvloeit. Studenten kunnen leerpaden kiezen en volgen al naargelang hun voorkeur.

De expert focus groepsinterviews geven waardevolle suggesties over SMILE Maker als probleemoplossend gereedschap te zien. Bij voorbeeld zou de SMILE probleem oplossingsmethode die werd ontworpen voor een generieke functie meer concrete domeinapplicaties moeten opleveren. Het uiterlijk van de facilitator zou hun denkproces niet mogen beïnvloeden. Ook zou de beschikbaarheid van creatieve probleemoplossingstechnieken de gebruikers niet boven het hoofd mogen groeien.

SMILE Maker moet gezien worden als een prototype voor het testen van ideeën over het verbeteren van het ontwerpproces. De evaluatie van het prototype toonde aan dat SMILE Maker een effectief gereedschap is voor probleemoplossen en geschikt als leergereedschap. Er is echter nog heel wat te verbeteren aan de probleemoplossingsmethode, de leeraanpak en vooral aan het gebruikersinterface. Het huidige project mikt op SMILE Maker als individueel gereedschap. Het lijkt een aantrekkelijk gezichtspunt om SMILE Maker verder door te ontwikkelen en te evalueren als ondersteuning voor groepsprocessen.

References

Ackoff, R. (1978). *The art of problem solving*. Chichester: John Wiley.

Ahlberg, M. (1993). Concept maps, vee diagrams and rhetorical argumentation analysis: three educational theory-based tools to facilitate meaningful learning. *Proceedings of the third International Seminar on Misconceptions and Educational Strategies in Science and Mathematic*, (pp. 1 –24). Ithaca, NY: Misconception Trust.

Akker,van der J.(1999). Principles and methods of development research. In J. van den Akker, R. Branch, K. Gustafson, N. Nieveen & T. Plomp (Eds.), *Design approaches and tools in education and training* (pp. 1-14). Dordrecht: Kluiver, Academic Publisher.

Anderson, J., (1983). *The architecture of cognition*. Harvard: Harvard University Press.

Ausubel, D, Novak, J., & Hanesian, H. (1978*). Educational psychology. A cognitive view*. New York: Holt, Rinehart and Winston.

Ayersman, D. & von Minden, A. (1995). Individual differences, computers, and instruction. *Computers in Human Behaviour*, 11 (3-4), 371-390.

Baer, J. (1993). *Creativity and divergent thinking: A task-specific approach*. Hilsdale, New Jersey: LEA.

Benjafield, J. G. (1996). *Cognition.* (Sec. ed.). New Jersey: Prentice-Hall.

Beyerbach, B. (1988). Developing a technical vocabulary on teacher planning: Pre-service teachers' concept maps. *Teaching and Teacher Education*, 4, 339-347.

Block, P. (2000). *Flawless consulting. A guide to getting your expertise used*. San Diego: University Associates.

Budgen, D. (1994). *Software design*. Wokingham: Adison-Wesley Publishing Company.

Buzan, T., & Buzan, B. (1996). *The Mind map.* Book. New York: Plume.

Campbell, D.T. (1960). Blind variation and selective retention in creative thought as in other knowledge processes. *Psychological Bulletin*, 67, 380-400.

Checkland, P. (1981). *System thinking, system practice*. Chichester: John Wiley.

Checkland, P., & Scholes, J. (1990). *Soft system methodology in action*. Chichester: John Wiley.

Clark, K., & Wheelwright, B. (1993*). Managing new product and process development*. New York: Harvard Business School, Free Press.

Clegg, B., & Birch, P. (1999). *Instant Creativity*. London: Kogan Page.

Collins, A., Brown, J.S., & Newman, S.E. (1989). Cognitive apprenticeship: teaching the crafts of reading, writing and mathematics. In L.B. Resnick (Ed.), *Knowing, learning, and instruction*. *Essays in Honor of Robert Glaser* (pp. 453-494). Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers.

Collis, B., & de Boer, W. (1999). The TeleTop decision support tool. In J. van den Akker, R. Branch, K. Gustafson, N. Nieveen & T. Plomp (Eds.), *Design approaches and tools in education and training* (pp. 235-248). Dordrecht: Kluiver, Academic Publisher.

Collis, B., Peters, O., & Pals, N. (2001). A model for predicting the educational use of information and communication technologies. *Instructional Science* 29, 95-125.

Concept Map Toolkit [Computer software]. (2000). University of Western Florida. Downloaded March 10, 2000 from WWW: http://cmap.coginst.uwf.edu

Conger, S. (1994). *The New software engineering*. Belmont, CA: Wadsworth Publishing Company.

Cotterell, M., & Hughes, B. (1996). *Software project management*. London: International Thomson Computer Press.

Cross, N. (2000). *Engineering design methods. Strategy for product design* (3d ed.). Chichester: John Wiley & Sons.

Dabbagh, N. H., Jonassen, D., Yueh, H-P., & Samouilova (2000). Assessing a problem-based learning approach to an introductory instructional design course: A case study. *Performance Improvement Quarterly*, 13 (3), 60-83.

Daniels, R., & Stevens, J.P. (1976). The interaction between the internal – external locus of control and two methods of college instruction*. American Educational Research Journal,* 13, 126-153.

De Bono, E. (1990). *Lateral thinking for management*. London: Penguin Books.

De Bono, E. (1992). *Teach your child how to think*. London: Viking.

De Bono, E. (1994). *Water Logic*. London: Penguin Books.

DeGrace, P., & Stahl, L. (1990*). Wicked problems, righteous solutions: A catalogue of modern software engineering paradigms*. Englewood Cliffs, New Jersey: Prentice Hall.

Decision Explorer® 3.1 [Computer Software]. (2000). Banxia® Software Limited.

Eden, C., & Ackerman, F. (1998). Analysing and comparing ideographic causal maps. In C. Eden and J-C. Spender (Eds), M*anagerial and organisational cognition. Theory, method, and research* (pp. 192-209). London: Sage.

Eden, C., Jones, S., & Sims, D. (1983). *Messing about in problems. An informal structured approach to their identification and management*. Oxford: Pergamon Press.

Eden, C.L., Ackerman, F., & Cropper, S. (1997). *Getting started with cognitive mapping*. Glasgow: Banxia Software.

Eisenstadt, M. (1978). *Cognitive psychology*. *Learning and problem solving*. Milton Keynes: Open University Press.

Entwistle, N. (1988). Motivational factors in approaches to learning. In R. Schmeck (Ed.), *Learning strategies and learning styles* (pp. 21-51). New York: Plenum Press.

Eysenck, M., & Keane, M. (1995). *Cognitive Psychology*. London: LEA.

Fryans, L., & Maehr, M. (1979). Attributional style, task selection, and achievement. *Journal of Educational Psychology 71,* 58-86.

Gaines, B., & Shaw, M. (1998). *Concept maps as hypermedia components*. Retrieved October 10, 1998 from WWW: http://www.cpsc.ucalgary.ca/~kremer/webnet96/webnet_kremer.html

Garvin, D. (2000). *Learning in action*. Boston: Harvard Business School Press.

Gilbert, J., & Han, C. (1999). Arthur: Adapting instruction to accommodate learning style. In P. Bra & J. Leggett (Eds), *Proceedings of Web Net'99 World Conference on WWW and Internet Honolulu, Hawaii* (pp. 433-438). Charlottesville, VA: AACE.

Grant, P. (1998). *Concept mapping*. Retrieved October, 10, 1998 from WWW: http://www.ozemail.com.au/~pjgrant/ConceptMapping.html

Guilford, J.P. (1967). *The nature of human Intelligence*. N.Y: McGraw-Hill.

Hale, S. (1998). *Concept Mapping*. Retrieved October 10, 1998 from WWW: http://www.dc.peachnet.edu/~shale/humanities/composition/handouts/concept.html

Hammond, N. (1998). *Concept-mapping as directed reflection*. Retrieved October 10, 1998 from WWW: http://xanadu.bournemouth.ac.uk/CD/HAMMOND/HAMMOND2.HTM

Hayes, J. (1978). *Cognitive Psychology*. *Thinking and creating*. Illinois: The Dorsey Press.

Hayes-Roth, B., Hayes-Roth, F. (1988). A cognitive model of planning. In A. Collins & E. Smith (Eds.), *Readings in cognitive science. A Perspective from psychology and artificial intelligence* (pp. 496-513). San Mateo, CA: Morgan Kaufman Publishers.

Heeren, E., & Kommers, P. (1992). *Flexibility of expressiveness: Critical factor in the design of concept. Mapping tools for learning*. In P. Kommers, et al. (Eds), *Cognitive tools for learning* (pp. 86-101). Berlin: Springer-Verlag.

Heiden, van der, K., & Eden, C. (1998). The theory and praxis of reflective learning in strategic making. In C.Eden & J-C. Spender (Eds), *Managerial and organisational cognition. Theory, method, and research* (pp. 58-75). London: Sage.

Hellriegel, Slocum,& Woodman (1992). *Organisational behaviour*. St. Paul, MN: West publishing company.

Hicks, M. (1993). *Problem solving in management. Hard, soft and creative approaches*. London: Charman & Hall.

Hodgson, A. M. (1999). *Hexagons for systems thinking*. Retrieved March 16, 1999 from WWW: http://www.orglearn.nl/Archives/Hexagons/hex1.rtft.html

Hofman, M. (1995). *Cognitive mapping methods. An exploratory study*. Breukelen: Nijenrode University Press.

Holloway, R. (1978). Locus of control and academic achievement. *Audio-Visual Instruction*, 23, 16-45.

Honey, P., &. Mumford, A. (1992) *The Manual of learning styles*. Maidenhead, Berkshire: Published and Distributed by Peter Honey.

Horn,R. Information mapping. Retrieved April 10, 1999 from WWW: http://www.infomap.com

Huai, H. (2000). *Cognitive styles: its relations to memory capacity and concept mapping*. (Doctoral Dissertation, University of Twente, The Netherlands). Enschede: Febodruck.

Human Performance System (2000). *Getting started with STELLA 7.0*. Tutorial

Hunt, D. (1998). *Process mapping*. New York: John Wiley & Sons.

Hunt, E. (1994). Problem solving. In R. Sternberg (Ed), *Thinking and problem solving* (pp. 215-235). San Diego: Academic Press.

Hutchinson, J., & Karznitz, R. (1994). *Design and problem solving in technology*. New York: Delmar Publishers.

Idons-For-Thinking 2.0 [Computer software, demo version]. (1999). Idon Software. Downloaded March, 16, 1999 from WWW: http://www.idonresources.com/demo.html

Inspiration® 6.0 [Computer software].(1999). Inspiration® Software, Inc.

Jay, R. (2000). *Book of the ultimate business creativity*. Oxford: Capstone.

Jenkins, M. (1998). The theory and practice of comparing causal maps. In C. Eden & J-C. Spender (Eds), *Managerial and organisational cognition. Theory, method, and research* (pp. 231-249). London: Sage

Jobes, J. A. (1983). *The importance of the application of a note taking technique on high risk students as related to locus of control*. A dissertation submitted to the graduate educational policies council in partial fulfilment of the requirements for the degree doctor of education Ball State University, Muncie, Indiana.

Jonassen, D., & Grabowski, B. (1993). *Handbook of individual differences, learning, and instruction.* New Jersey*: LEA.*

Jonassen, D., Mayes, T. & McAleese, R. (1993). A manifesto for constructivist approach to use of technology in higher education. In T. Duffy, T. Lowick, D. Jonassen, & T. Welsh (Eds), *Designing the Environments for Constructive Learning* (pp. 123-167). Berlin: Springer-Verlag.

Jonassen, D., Beissner. K., & Yacci, M. (1993). *Structural knowledge*. New Jersey: LEA.

Jonassen, D., Reeves, T., Hong, H., Harvey, D., & Peters, K. (1998). Concept mapping as cognitive learning and assessment tools. *Journal of Interactive Learning Research, 8* (3/4) 289-308.

Jonassen, D., & Marra, R. (1998). Concept mapping and other formalisms as mindtools for representing knowledge. Retrieved October, 10, 1998 from WWW: http://www.icbl.hw.ac.uk/~granum/class/altdocs/dav_alt.htm

Jung, C.G. (1923). *Psychological types*. London: Routledge & Kegan Paul.

Kagan, J. (1965). Individual differences in the resolution of response uncertainty. *Journal of Personality and Social Psychology*, 2, 154-160.

Kaufmann, G. (2001). Problem solving and creativity. In J. Henry (Ed.), *Creative management* (pp. 47-78). London: Sage.

Keirsey, D., & Bates, M. (1998). *Please understand me. Character & temperament types*. Del Mar, CA: Prometheus Nemesis.

Kelly, G. (1955). *The psychology of personal constructs*. New York: Norton.

Kennedy, D., & McNaught (1998). Use of concept mapping in the design of learning tools for interactive multimedia. *Journal of Interactive Learning Research*, 8 (3/4) 389-406.

Kepner, Ch., & Tregoe, B. (1981). *The new rational manager*. London: John Martin Publishing.

Kessels, J. (1999). A relational approach to curriculum design. In J. van den Akker, R. Branch, K. Gustafson, N. Nieveen, & T. Plomp (Eds.), *Design approaches and tools in education and training* (pp. 59-70). Dordrecht: Kluiver, Academic Publisher.

Kirton, M. J. (1994). *Adaptors and innovators: styles of creativity and problem solving*. London: International Thomson Press.

Knirk, F., & Gustafson, K. (1986). *Instructional Technology*. New York: Holt, Runehart and Winston.

Kolb, D. (1998) *Experiential Learning*. Englewood Cliffs, New York: Prentice-Hall.

Kommers, P. (2000). Four stages in designing educational hypermedia. *International Journal of Continuing Engineering Education and Life-Long Learning*, 10 (1-4), 142-166.

Kommers, P., & Lanzing, J. (1998). Students' concept mapping for hypermedia design: Navigation through world wide web (www) space and self-assessment. *Journal of Interactive Learning Research*, 8 (3/4) 421-456.

Kommers, P., & Stoyanov, S. (1998). Concept mapping: Methodology, tools and educational practice. Pre-conference workshop (Saturday, June 20th). ED-MEDIA/ED-TELECOM Conference, Freiburg, Germany.

Kommers, P. A. M., Ferreira, A. F., & Kwak, A. W. (1998). *Document management for hypermedia design*. Berlin: Springer.

Krathwohl, D. (1993). *Methods of educational and social science research. An integrated approach*. New York: Longman.

Kremer, R., & Gaines, B. R. (1998). *Embedded interactive concept maps in Web documents*. Retrieved October 10, 1998 from WWW: http://www.cpsc.ucalgary.ca/~kremer/webnet96/webnet_kremer.html,

Laffey, J., & Singer, J. (1998). Using mapping for cognitive assessment in project-based science. *Journal of Interactive Learning Research*, 8 (3/4), 363- 388.

Lambiotte, J., Dansereau, D., Cross, P., & Reynolds, S. (1989). Multirelational semantic maps. *Educational Psychology Review*, 1(4), 331 - 366.

Lane, D. (1997). Modelling as learning: A consultancy methodology. In J. Morecroft & J. Sterman (Eds.), *Modeling for learning organizations* (pp. 93 – 120). Portland, Oregon: System Dynamics Series, Productivity Press.

Laukkanen, M. (1998). Conducting causal mapping research: opportunities and challenges. In C. Eden & J-C. Spender (Eds), *Managerial and organisational cognition theory, method, and research* (pp. 168-191). London: Sage.

Lawson, M.J. (1994). Concept Mapping. In T. Husen, & T.N.Postlethwaite (Eds), *The International Encyclopaedia of Education*. V.2 (pp. 1026 – 1031). Oxford: Elsevier Science..

Lefcourt, H.M. (1980). Locus of control and coping with life events. In E. Staub (Ed.), *Personality. Basic aspects and current research* (pp. 200-235). New Jersey: Prentice-Hall.

Lubart, T. I. (1994). Creativity. In R. Sternberg (Ed), *Thinking and problem solving* (pp. 290-334). San Diego: Academic Press.

Maier, N.R.F. (1970). *Problem solving and creativity in individuals and groups*. Belmont, CA: Wadsworth.

March, J., & Simon, H. (1993). *Organizations*. Cambridge, Massachusetts: Blackwell.

Maslow, A. (1970). *Motivation and personality*. New York: Harper & Row.

McAleese, R. (1998). *A theoretical view on concept mapping*. Retrieved October 10, 1998 from WWW: http://www.icbl.hw.ac.uk/~granum/class/altdocs/ray_alt.htm

McCabe, D. (1997). *Concept mapping workshop*. Retrieved September 12, 1997 from WWW: http://158.132.100.221/CMWkshp_folder/CncptMapp.Wkshop.html#CONTENTS

McClelland, J.L., & Rumelharrt, D.E. (1988). *Explorations in parallel distributed processing: A handbook of models, programmes and exercises*. Cambridge, MA: MIT Press.

McNeese, M. D., Zaff, B., Citera, M., Brown, C., & Whitaker, R. (1995). ACADAM: Eliciting user knowledge to support participatory ergonomics. *International Journal of Industrial Ergonomics*, 15, 345-363.

Mednick, S.A. (1962). The associative basis of the creative process. *Psychological Review*, 69, 220-227.

Merriënboer, van J. J. G. (1997). *Training complex cognitive skills. A four-component instructional design model for technical training*. Englewood Cliffs, New Jersey: Educational Technology Publications.

Messick, S. (1994) Cognitive style and learning. In T. Husen, & T.N.Postlethwaite (Eds), *The International Encyclopaedia of Education*. V.2 (pp. 868-872). Oxford: Elsevier Science.

Michalko, M. (1998). *Cracking creativity*. Berkeley, California: Ten Speed Press.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis*. (Sec. Ed.). Thousand Oaks: Sage Publication.

Miller, G.A. (1956). The magic number seven, plus or minus two. *Psychological Review*, 63, 81-97.

Mind Manager™ 4.0 [Computer software].(1998). MindJet LLC.

Mintzberg, H. (1992). The Manger's job: Folklore and fact. In: H. Mintzberg, & J. B. Quin. *The strategy process concepts and contexts* (pp.21-31). Englewood Cliffs, New Jersey: Prentice Hall.

Moonen, J. (1999). The design and prototyping of digital learning materials. Some new perspectives in design approaches. In J. van den Akker, R. Branch, K. Gustafson, N. Nieveen, & T. Plomp (Eds.), *Design approaches and tools in education and training* (pp. 95-111). Dordrecht: Kluiver, Academic Publisher.

Moonen, J. (2000). A three space design strategy for digital learning material. *Educational Technology*, 40 (2), 26-32.

Moonen, J. (in press). Design methodologies. In H. Adelsberger, B. Collis, & J. Pawlowski (Eds), *Handbook of information technologies for education and training*. Berlin: Springer Verlag.

Morecroft, J. D. M. (1997). Executive knowledge, models and learning, In J. Morecroft & J. Sterman (Eds.), *Modeling for learning organizations* (pp. 3 – 28). Portland, Oregon: System Dynamics Series, Productivity Press.

Myers, K., & Briggs, I. (1993). *Introduction to type*. Palo Alto, CA: Consulting Psychologists Press.

Newell, A., & Simon, H. (1972). *Human problem solving*. Englewood Cliffs, New York: Prentice Hall.

Norman, D. (1993). *Things that make us smart: defending human attributes in the age of machine*. Reading, MA: Addison-Wesley.

Novak, J., & Gowin, D. (1984). *Learning how to learn*. Cambridge: Cambridge University Press.

Novak, J. (1998). *Learning, creating and using knowledge. Concept maps™ as facilitative tools in schools and corporation*. Mahwah, New Jersey: LEA.

Oughton, J. M., & Reed, W. M. (2000). The effect of hypermedia knowledge and learning styles on student-centered concept maps about hypermedia. *Journal of research on computing in education*, 32 (3), 366 – 383.

Pask, G. (1988). Learning strategies, teaching strategies, and conceptual or learning style. In R. Schmeck (Ed), *Learning, strategies and learning styles* (pp. 83-100). New York: Plenum Press.

Patton, M. Q. (1990). *Qualitative evaluation and research methods* (Sec. ed.). London: Sage Publication.

Pedley, B., Bretz, R., & Novak, J. (1994). Concept maps as a tool to assess learning in chemistry. *Journal of Chemical Education*, 71 (1), 35-67.

Perkins, D. N. (1993). Person-plus: distributed view of thinking and learning. In G. Salomon (Ed), *Distributed cognitions* (pp. 88-111). Cambridge: Cambridge University Press.

Piaget, J. (1977). *The development of thought*. Oxford: Blackwell.

Pilgrim, C. J., & Leung, Y. K. (1999). Site Maps – Where are we now? In P. Bra & J. Leggett (Eds), *Proceedings of Web Net'99 World Conference on WWW and Internet, Honolulu, Hawaii* (pp. 883-888). Charlottesville, VA: AACE.

Quillian, M.R. (1988) Semantic memory. In A. Collins & E. Smith (Eds.), *Readings in cognitive science. A Perspective from psychology and artificial intelligence* (pp 80-101). San Mateo, CA: Morgan Kaufman Publishers.

Reader, W., &. Hammond, N. (1994). Computer-based tools to support learning from hypertext: concept mapping tool and beyond. *Computers education*, 22, (1/2) 45-78.

Reimann, P. (1999). The role of external representations in distributed problem solving. *Learning and Instruction*, 9, 411-418.

Riding, R., & Rayner, S. (1998). *Cognitive styles and learning strategies. Understanding style differences in learning and behaviour*. London: David Fulton Publishers.

Richey, R. C., & Nelson, W. A. (1996). Development research. In D. Jonassen (Ed). *Handbook of research for educational communications and technology* (1213-1246). New York: Simon & Schuster Macmillian.

Rogers, Y. (1997). A brief introduction to distributed cognition. Retrieved July 24, 1997 from WWW: http://www.cogs.susx.ac.uk/users/yvonner/dcog.html

Ros, J. (2000). *The book of ultimate business creativity*. Oxford: Capstone.

Rotter, J.B. (1982). *The development and application of social learning theory*. New York: Praeger.

Rumelhart, D.E., Smolensky, P., McClelland, J.L., & Hinton, G.E. (1988). Schemeta and sequential thought process in PDP Models. In A. Collins & E. Smith (Eds.), *Readings in cognitive science. A Perspective from psychology and artificial intelligence* (pp. 224-249). San Mateo, CA: Morgan Kaufman Publishers.

Salomon, G. (1993). No distribution without individuals' cognition: a dynamic interactional view. In G. Salomon (Ed), *Distributed cognitions* (pp. 111-139). Cambridge: Cambridge University Press.

Saveney, W., & Robinson, R. S. (1996). Qualitative research issues and methods: An introduction for educational technologists. In D. Jonassen (Ed), *Handbook of research for educational communications and technology* (1213-1246). New York: Simon & Schuster Macmillian.

Schank, R.C., & Abelson, R.R. (1988). Scripts, plans, goals and understanding. In A. Collins & E. Smith (Eds.), *Readings in cognitive science. A Perspective from psychology and artificial intelligence* (pp. 190-213). San Mateo, CA: Morgan Kaufman Publishers.

Schein, E. (1999). *Process consultation revisited. Building and helping relationship*. Addisson-Wesley: Reading, Massachusetts.

Schön, D. (1996). *The reflective practitioner. How professionals think in action*. London: Arena.

Sherry, L., & Trigg, M. (1996). Epistemic forms and epistemic games. *Educational Technology, 36*(3), 38-44.

Simon, H. (1972). *The science of artificial*. Cambridge, Massachusetts: MIT Press.

Simon, H. (1977). *The new science of management decision*. Englewood Cliffs, New York: Prentice-Hall.

Simonton, D.K. (1993). Genius and chance: A Darwinian perspective. In J. Brockman (Ed). *Creativity* (123-156). New York: Simon & Schuster.

Smits, T., & van Dijk, R. (1999). *Attitudes toward concept mapping*. Students experiment assignment (Onderzoeksopdracht 1998-1999). Unpublished report. University of Twente, TO, The Netherlands.

Spender, J.-C. (1998). The dynamics of individual and organisational knowledge. In C. Eden & J.-C. Spender (Eds.), *Managerial and organisational cognition* (pp. 13 – 39). London: Sage Publication.

Spiro, R., & Jehng, J.-C. (1990). Cognitive flexibility and hypertext: theory and technology for the nonlinear and multidimensional traversal of complex subject matter. In D. Nix & R. Spiro (Eds.), *Cognition, education and multimedia. Exploring ideas in high technology* (pp. 163-205). Hillsdale, New Jersey: LEA.

Stahl, G. (1993). Interpretation in design: the problem of tacit and explicit understanding in computer support of cooperative design. *A Ph.D. thesis submitted to the Faculty of the Graduate School, University of Colorado, Department of Computer Science*.

STELLA 7.0 [Computer software, demo version]. (2000). High Performance System, Inc. The System Thinking Company™. Downloaded November 19, 2000 from WWW: http://www.hps-inc.com/

Sternberg, R. (1994). Thinking styles: theory and assessment at the interface between intelligence and personality. In R. Sternberg, & P. Ruzgis (Eds.), *Personality and intelligence* (pp. 56-89). Cambridge, University Press.

Stewart, V. (2000). Business applications of repertory grid. Retrieved March 12, 2000 from WWW: http://www.EnquireWithin.co.nz/busiChap1.html

Tekinerdogan, B. (2000). *Synthesis-based software architecture design*. (Doctoral dissertation, University of Twente, The Netherlands). Enschede: Print Partners Ipskamp.

The Information Mapping® Method. (1999). 30 years of research. Research paper & notes. Information Mapping, Inc.

Torrance, E.P. (1988). Creativity as manifest in testing. In R. J. Sternerg (Ed), *The nature of creativity* (pp. 43-75). Cambridge: Cambridge University Press.

Trochim,W. (1997). Concept mapping: Soft science or hard art? Retrieved October 10, 1997 from WWW: http://trochim.human.cornell.edu/research/epp2/epp2.htm,

Trochim, W. (2000). Concept system. Retrieved May 25, 2000 from WWW: http//www.conceptsystems.com

Tsinakos, A., & Margaritis, K. (1999). Student modelling review. What can be learned for distance education? In P. Bra & J. Leggett (Eds.), *Proceedings of WebNet'99 World Conference on WWW and Internet, Honolulu, Hawaii* (pp. 1071-1077). Charlottesville, VA: AACE.

Van Gundy, A. (1992). *Idea power. Techniques & resources to unleash the creativity in your organisation*. New York: Amacom

Van Gundy, A. (1997). *Techniques of structured problem solving*. New York: Van Nostrand.

Vennix, J. A. M. (1997). *Group model building. Facilitating team learning using system dynamics.* Chichester: John Wiley & Sons.

Vilberg, T. (1997). *Using concept mapping in a sensation & perception course*. Retrieved October 10, 1997 from WWW: http://river.clarion.edu/TRVILBERG/conceptmap.html

Visscher-Voerman, I., Gustafson, K., & Plomp, T. (1999). Educational design and development. An overview of paradigms. In J. van den Akker, R. Branch, K. Gustafson, N. Nieveen, & T. Plomp (Eds.), *Design approaches and tools in education and training* (pp. 15-28). Dordrecht: Kluiver, Academic Publisher.

Wagner, R. (1992). Managerial problems solving, In: R. Sternberg, & P. Frensch (Eds.), *Complex problem solving* (159-184*).* Hillsdale, New Jersey: LEA.

Wandersee, J. (1990). Concept mapping and the cartography of cognition. *Journal of Research in Science Teaching*, 27 (10), 923-936.

Wertheimer, M. (1987). *Productive thinking*. New York: Harper & Brothers Publishers. (Original work published 1943)

Wieseler, W., Katzman, J., Larsen, J., & Caton, J. (1999). *RIO: A standards-based approach for reusable information objects*. Cisco Systems, Inc.

Willerman, M., & Harg, R. A. (1991) The concept map as an advance organizer. *Journal of Research in Science Teaching*, 28, (8), 705-711.

Witkin, H.A., & Goodenough, D. R. (1981). *Cognitive styles. Essence and origins: field dependence and field independence*. New York: International University Press.

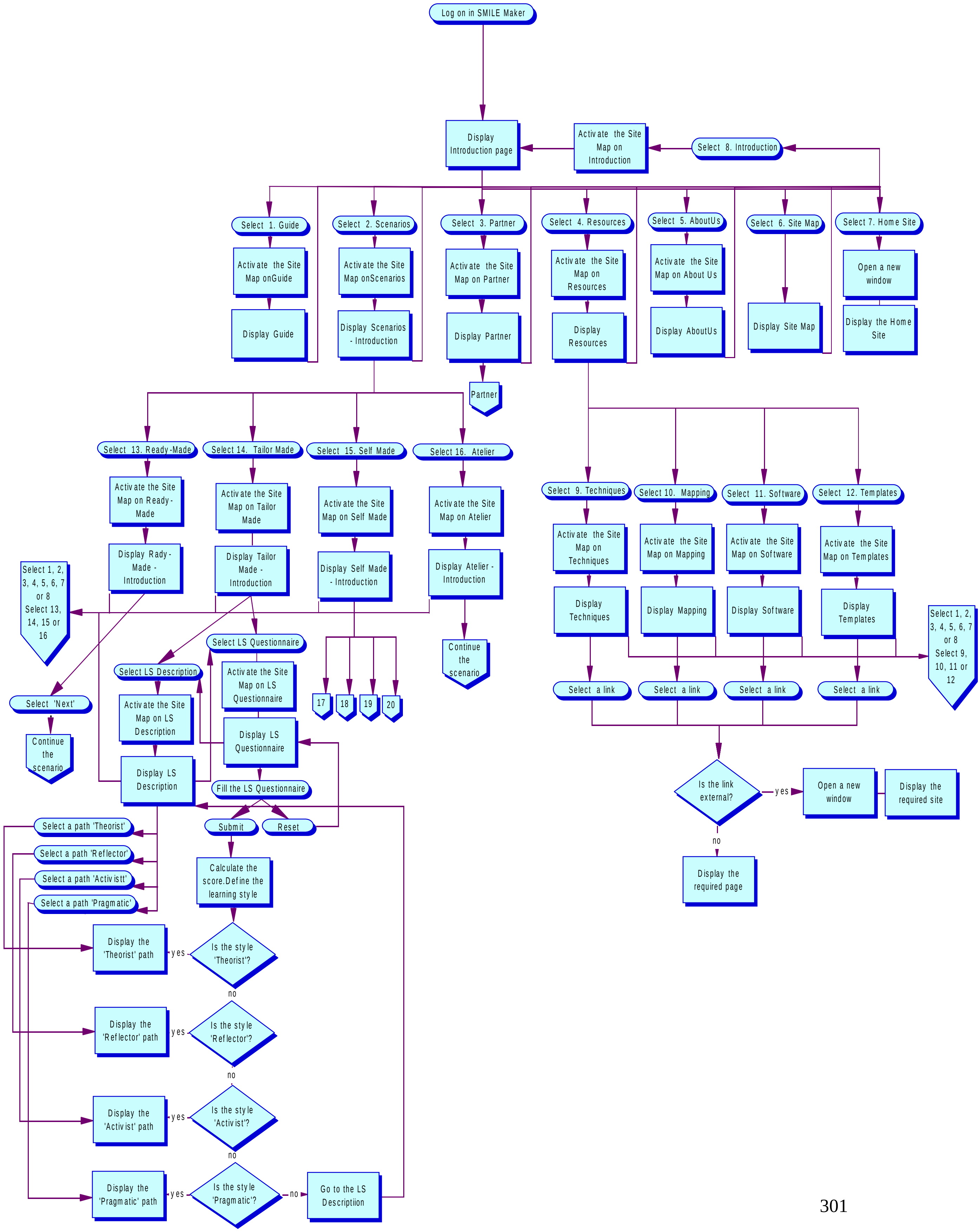
Wittgenstein, L. (1988). *Traetatus logico-philosophicus* (Translation in Bulgarian). Sofia: Science and Art. (Original work published 1956)

Wodtke, M. von (1993). *Mind over media*. New York: McGraw-Hill.

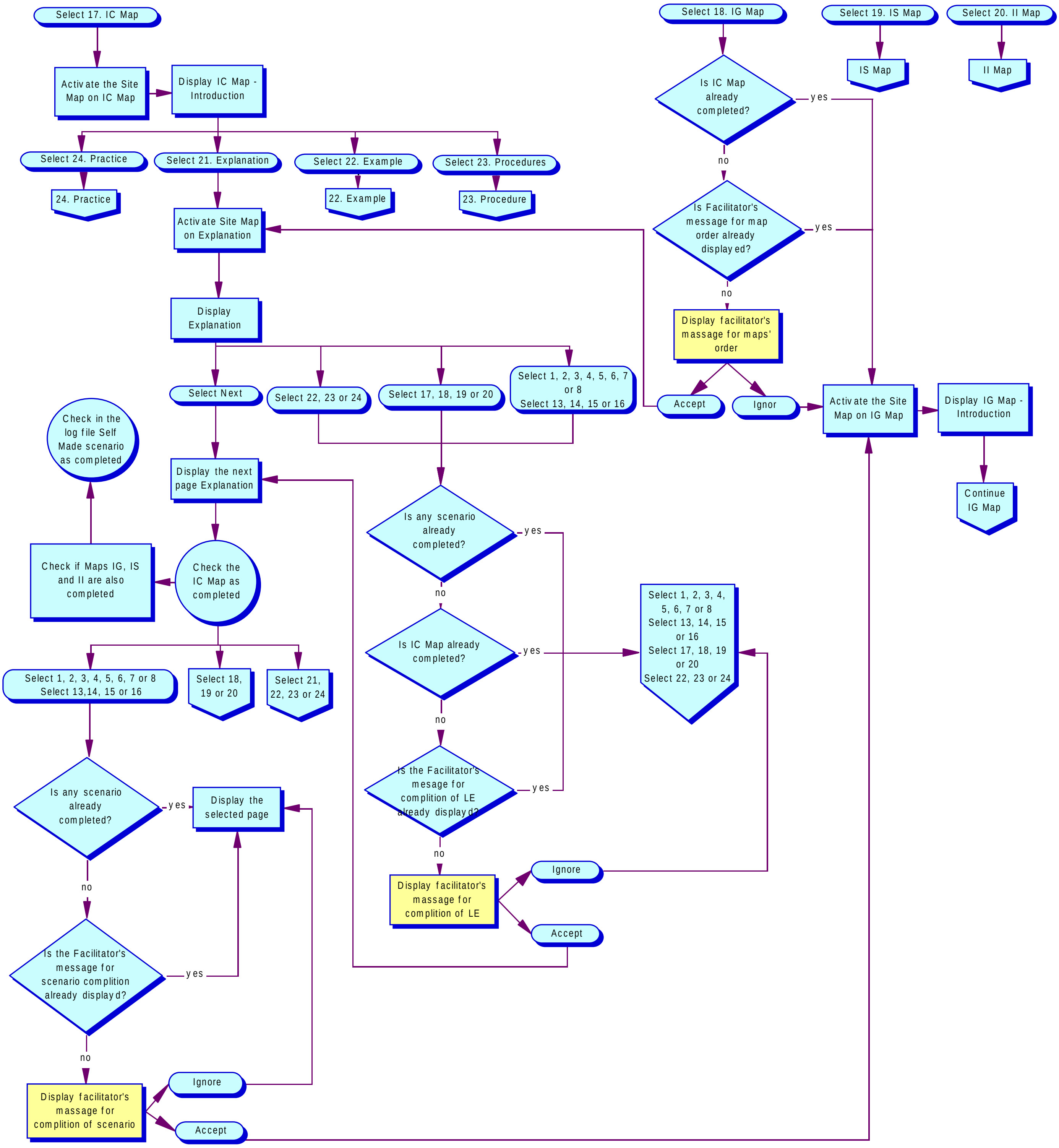
Zaff, B., McNeese, M., & Snyder, D. (1993). Capturing multiple perspectives: a user-centred approach to knowledge and design acquisition. *Knowledge Acquisition*, 1993, 5, 79-116.

Appendices

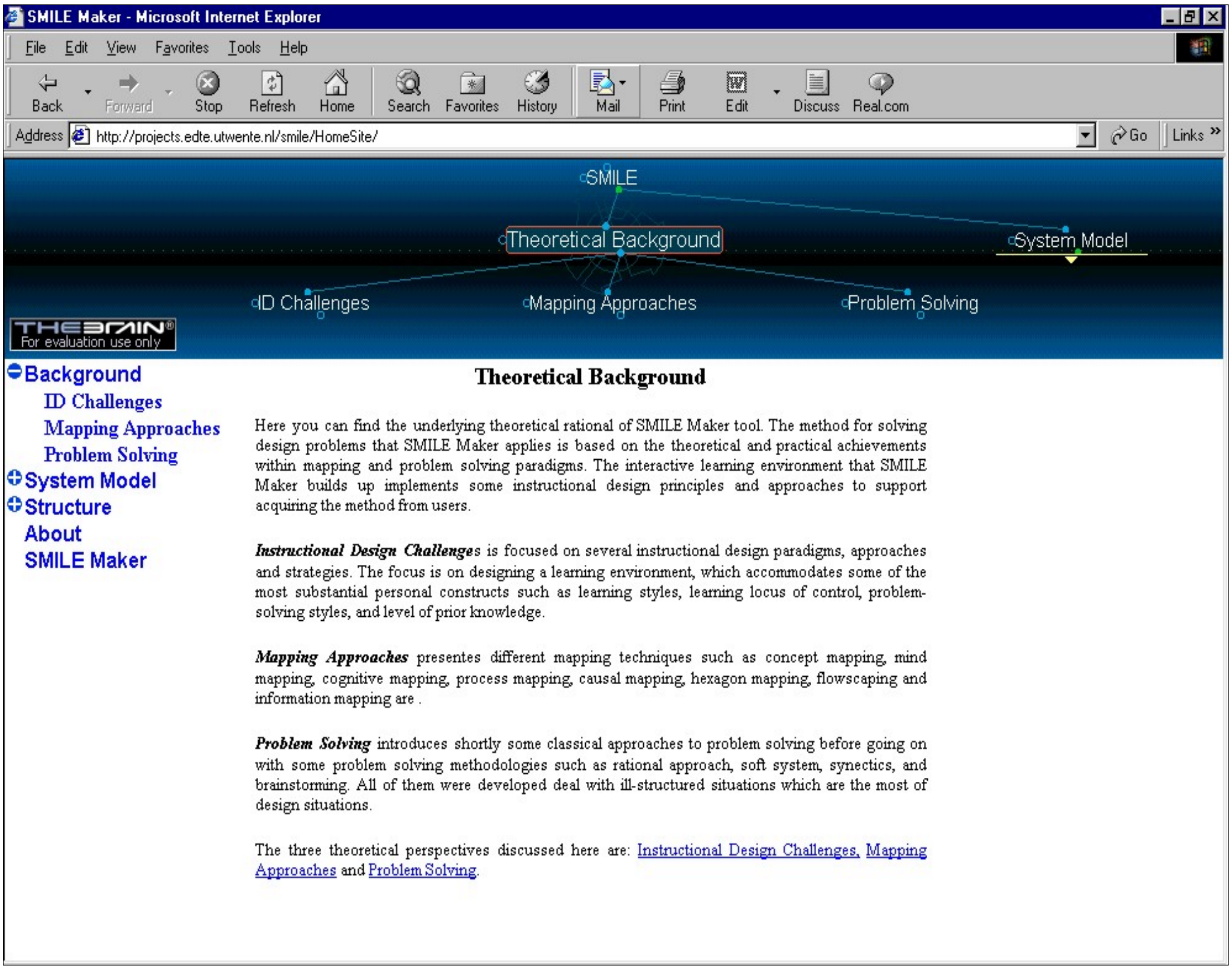
Appendix 1. The SMILE Maker design - a sample of the functionality flowchart: the main options.



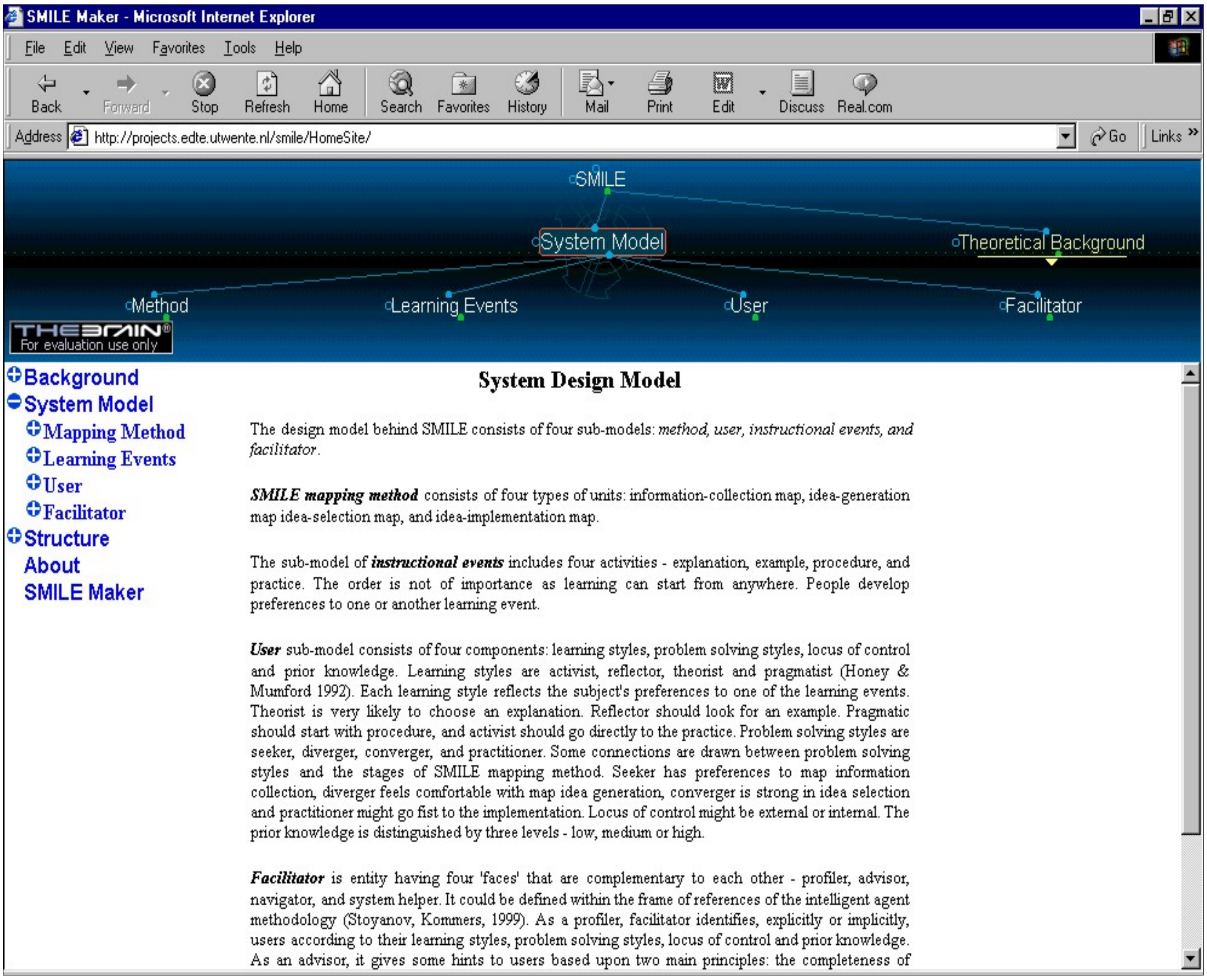
Appendix 2. The SMILE Maker design - a sample of the functionality flowchart: Self-made scenario



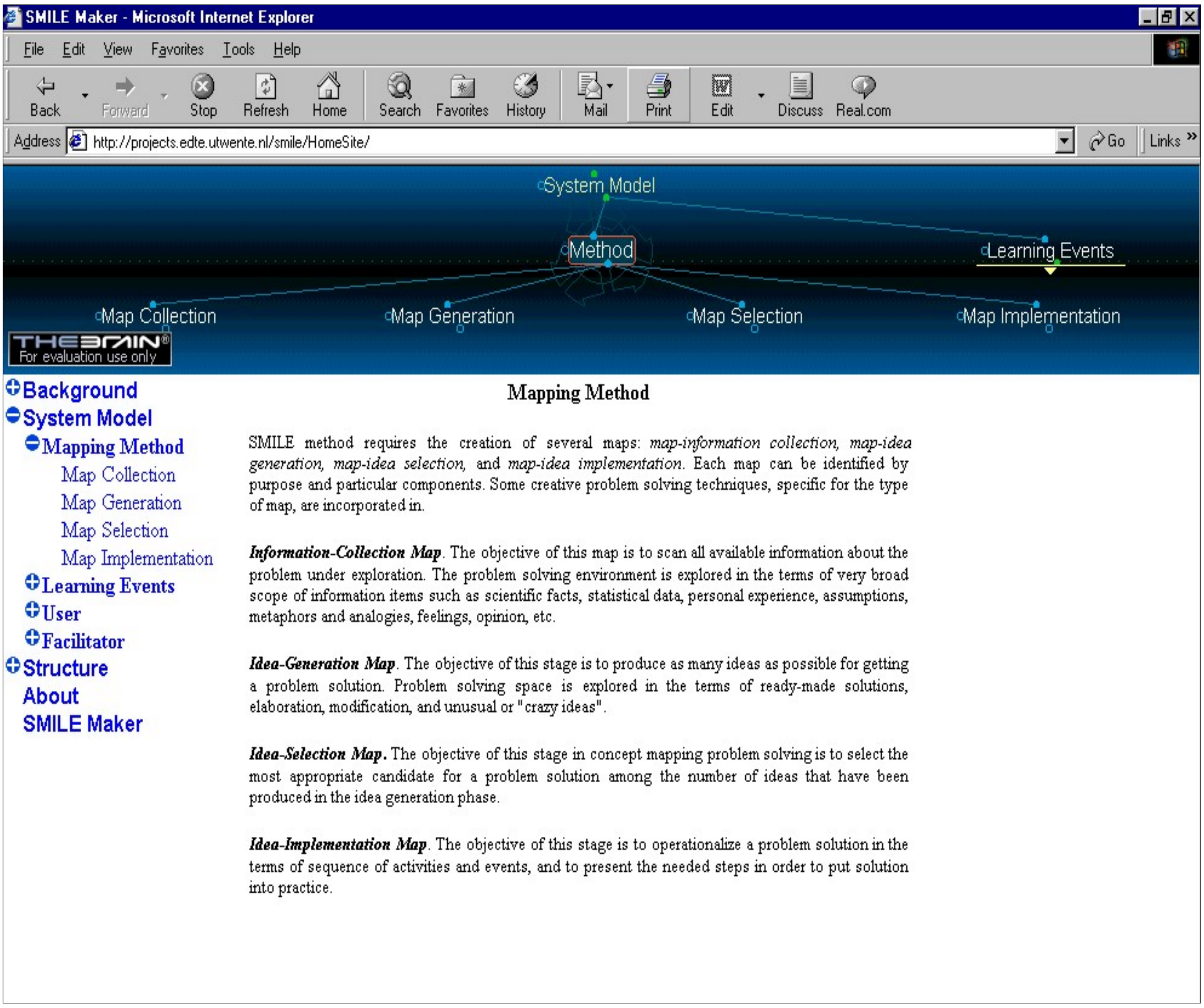
Appendix 3. The SMILE Maker supportive Web site – 'Theoretical background'



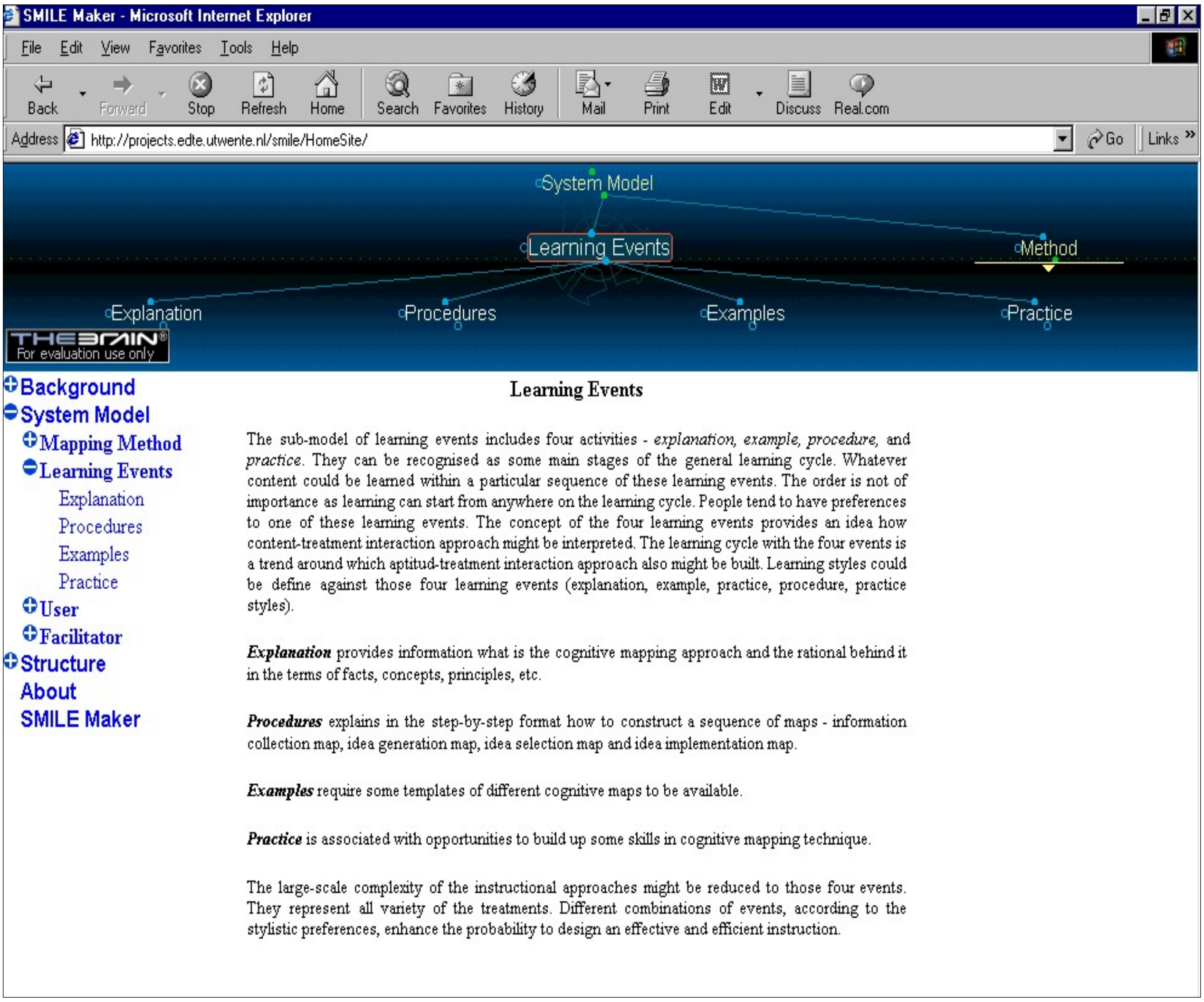
Appendix 4. The SMILE Maker supportive Web site – 'System design model'



Appendix 5. The SMILE Maker supportive Web site – 'Mapping method'



Appendix 6. The SMILE Maker supportive Web site – 'Learning events'



Learning Events

The sub-model of learning events includes four activities - *explanation, example, procedure,* and *practice*. They can be recognised as some main stages of the general learning cycle. Whatever content could be learned within a particular sequence of these learning events. The order is not of importance as learning can start from anywhere on the learning cycle. People tend to have preferences to one of these learning events. The concept of the four learning events provides an idea how content-treatment interaction approach might be interpreted. The learning cycle with the four events is a trend around which aptitud-treatment interaction approach also might be built. Learning styles could be define against those four learning events (explanation, example, practice, procedure, practice styles).

Explanation provides information what is the cognitive mapping approach and the rational behind it in the terms of facts, concepts, principles, etc.

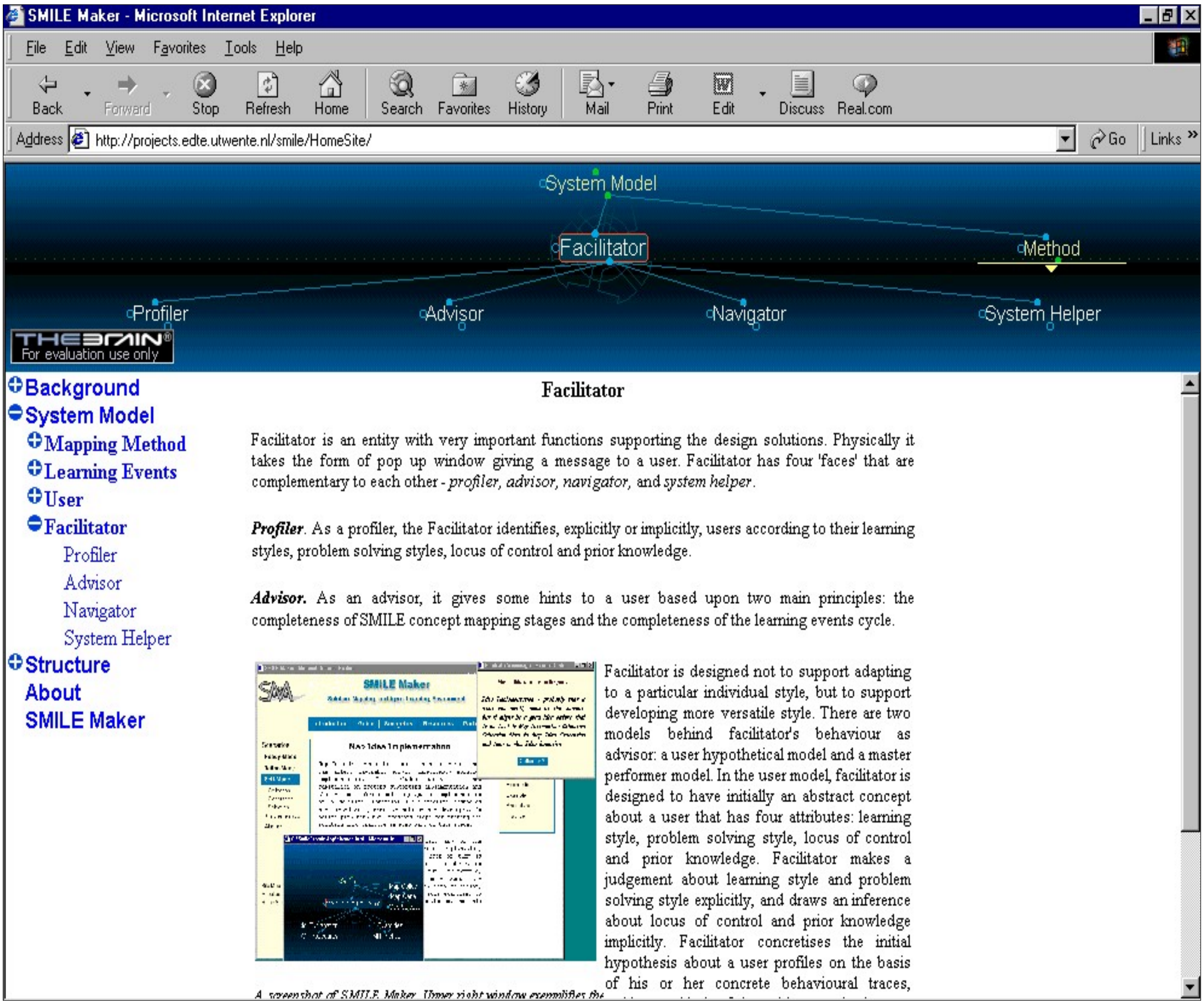
Procedures explains in the step-by-step format how to construct a sequence of maps - information collection map, idea generation map, idea selection map and idea implementation map.

Examples require some templates of different cognitive maps to be available.

Practice is associated with opportunities to build up some skills in cognitive mapping technique.

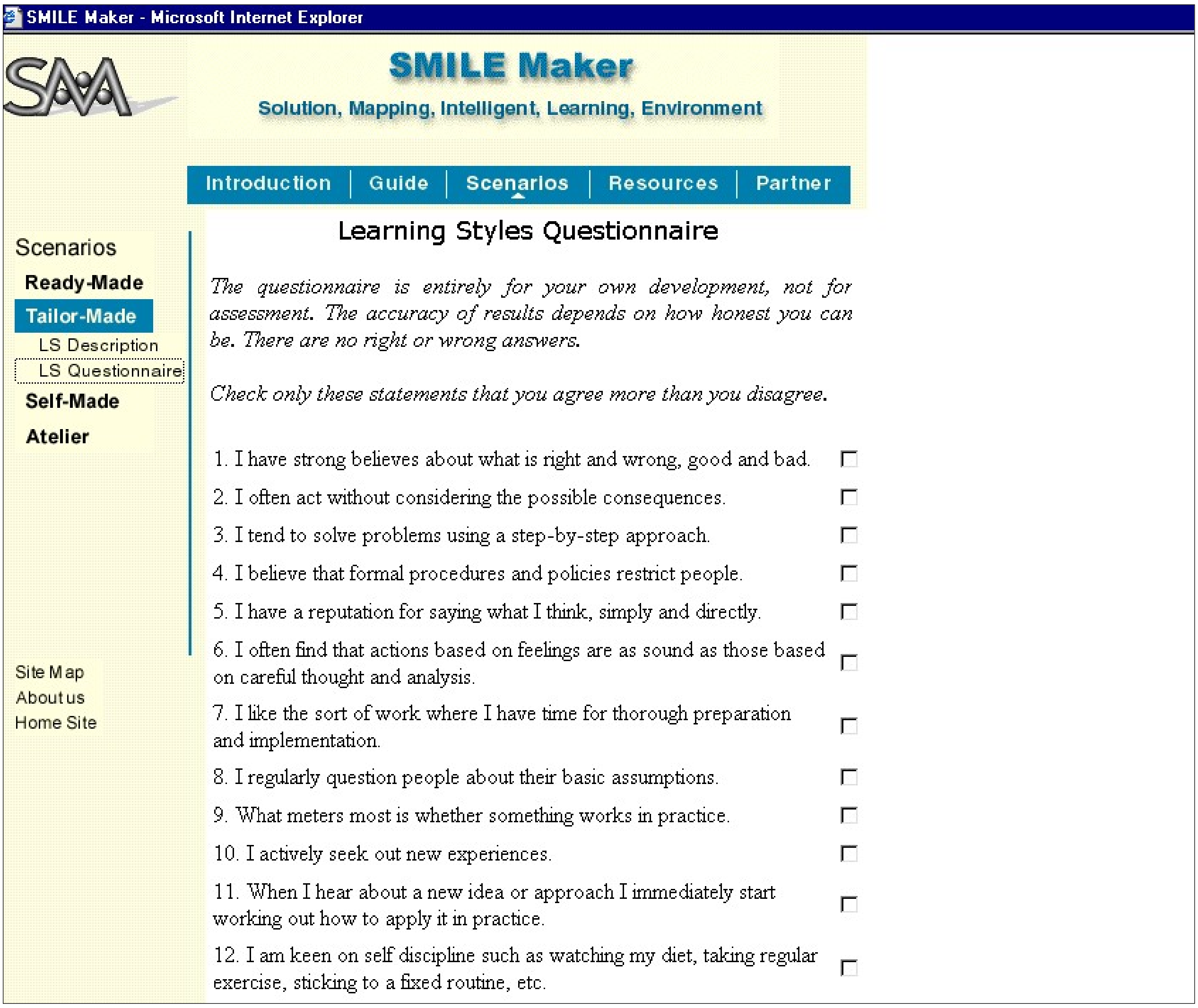
The large-scale complexity of the instructional approaches might be reduced to those four events. They represent all variety of the treatments. Different combinations of events, according to the stylistic preferences, enhance the probability to design an effective and efficient instruction.

Appendix 7. The SMILE Maker supportive web site – 'Facilitator'



Appendix 8. The SMILE Maker – 'Guide'

Appendix 9. The SMILE Maker – 'Learning styles questionnaire'



SMILE Maker - Microsoft Internet Explorer

SMILE Maker

Solution, Mapping, Intelligent, Learning, Environment

Introduction | Guide | Scenarios | Resources | Partner

Scenarios
- Ready-Made
- Tailor-Made
  - LS Description
  - LS Questionnaire
- Self-Made
- Atelier

Site Map
About us
Home Site

Learning Styles Questionnaire

The questionnaire is entirely for your own development, not for assessment. The accuracy of results depends on how honest you can be. There are no right or wrong answers.

Check only these statements that you agree more than you disagree.

1. I have strong believes about what is right and wrong, good and bad. ☐
2. I often act without considering the possible consequences. ☐
3. I tend to solve problems using a step-by-step approach. ☐
4. I believe that formal procedures and policies restrict people. ☐
5. I have a reputation for saying what I think, simply and directly. ☐
6. I often find that actions based on feelings are as sound as those based on careful thought and analysis. ☐
7. I like the sort of work where I have time for thorough preparation and implementation. ☐
8. I regularly question people about their basic assumptions. ☐
9. What meters most is whether something works in practice. ☐
10. I actively seek out new experiences. ☐
11. When I hear about a new idea or approach I immediately start working out how to apply it in practice. ☐
12. I am keen on self discipline such as watching my diet, taking regular exercise, sticking to a fixed routine, etc. ☐

Appendix 10. The SMILE Maker – reflector's learning path


SMILE Maker - Microsoft Internet Explorer

SMILE Maker

Solution, Mapping, Intelligent, Learning, Environment

Introduction | Guide | Scenarios | Resources | Partner

Scenarios
Ready-Made
Tailor-Made
LS Description
LS Questionnaire
Self-Made
Atelier

Site Map
About us
Home Site

What follows is supposed to be your preferred way of learning. It has been built up around the learning event of examples. Some explanations and procedures are also available before a practice of this type of map to be suggested.

This section presents a set of examples representative of the way in which SMILE mapping has been applied to a particular case. As you already know SMILE mapping consists of four type of maps to be developed: map information collection, map idea generation, map idea selection, map idea implementation.

Map Information Collection

The first type of map to be presented is the map information collection. Please read first the case and then take a look through examples.

To see the examples you should download Inspiration.

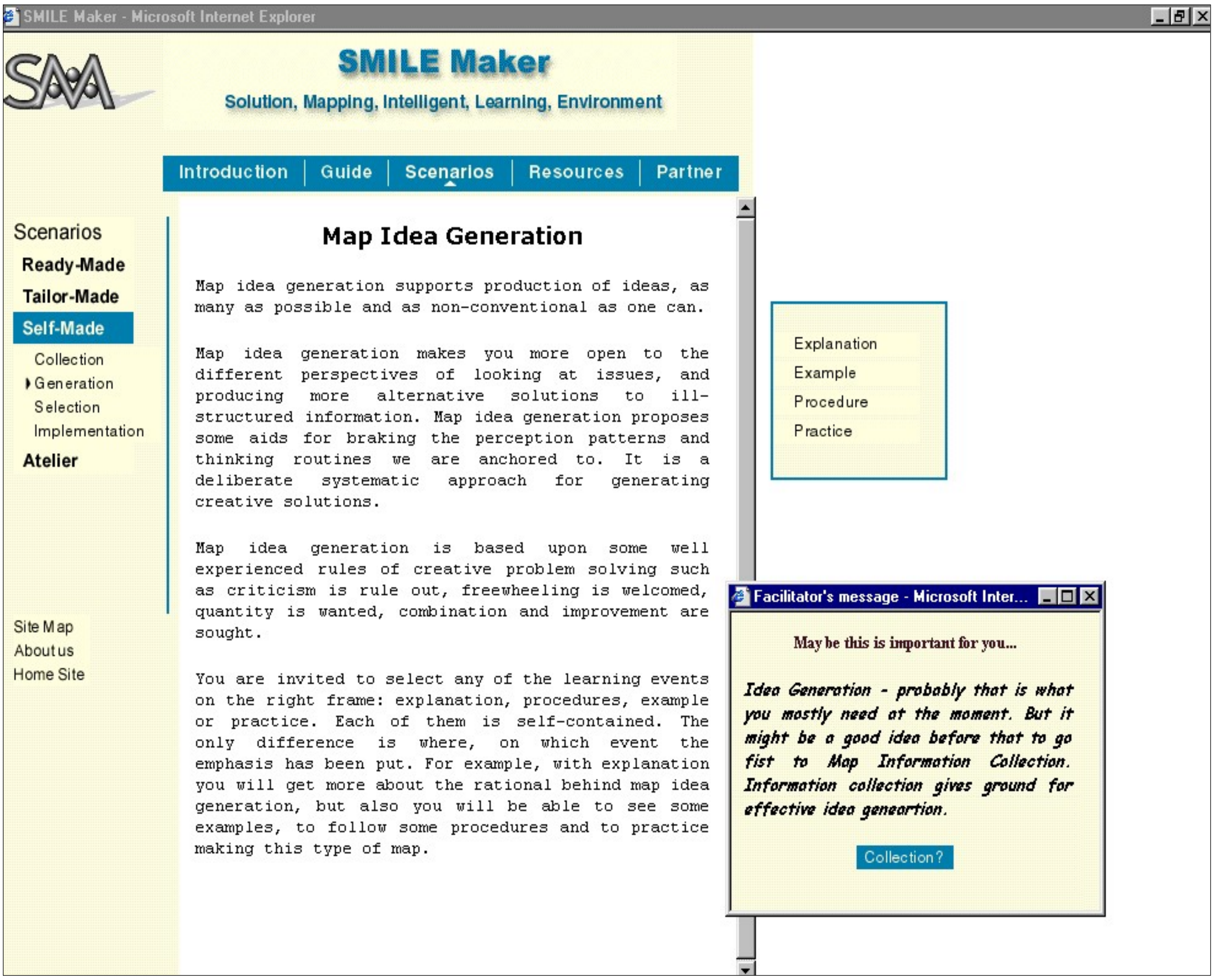
1. Map information collection after the free association stage
2. Map information collection after setting relationships stage
3. Map information collection after reshaping stage

With map information collection you are supposed to get a whole picture of a problem situation. This type of map help you to escape from missing important information.

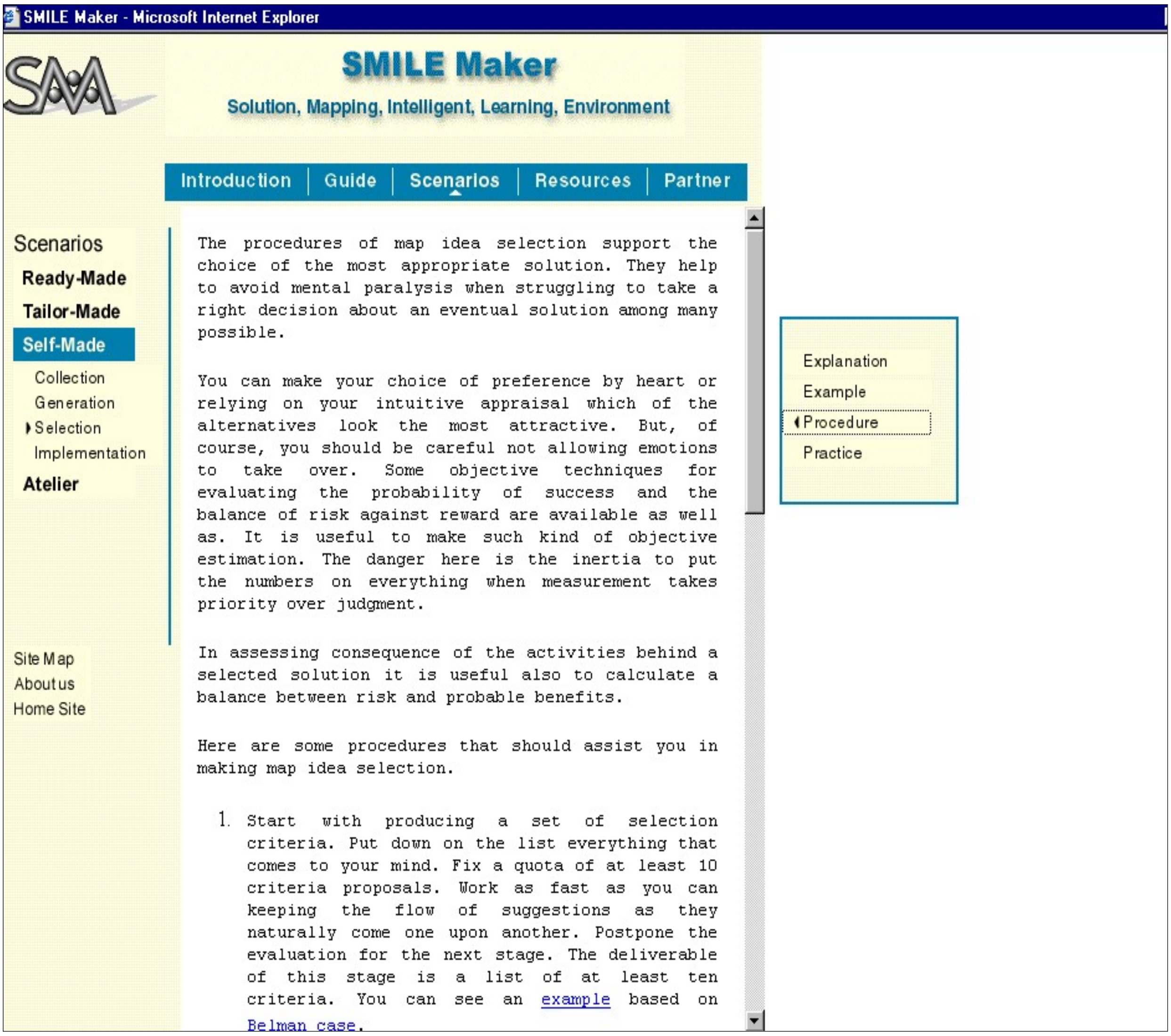
Information in the context of map information

Appendix 11. The SMILE Maker – activist's learning path

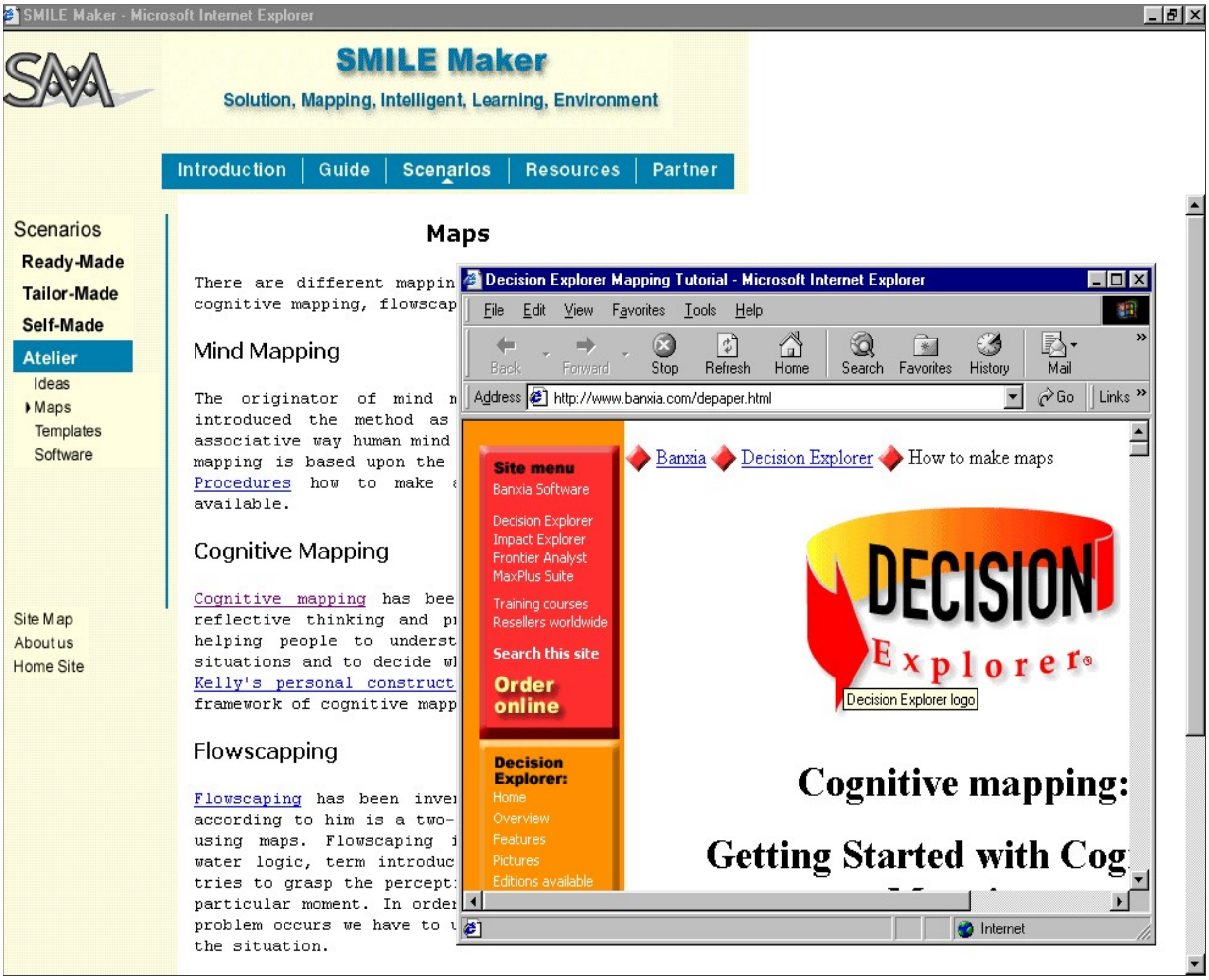
Appendix 12. The SMILE Maker – facilitator's message in the self-made scenario



Appendix 13. The SMILE Maker – a selected learning event in the self-made scenario



Appendix 14. The SMILE Maker – atelier scenario



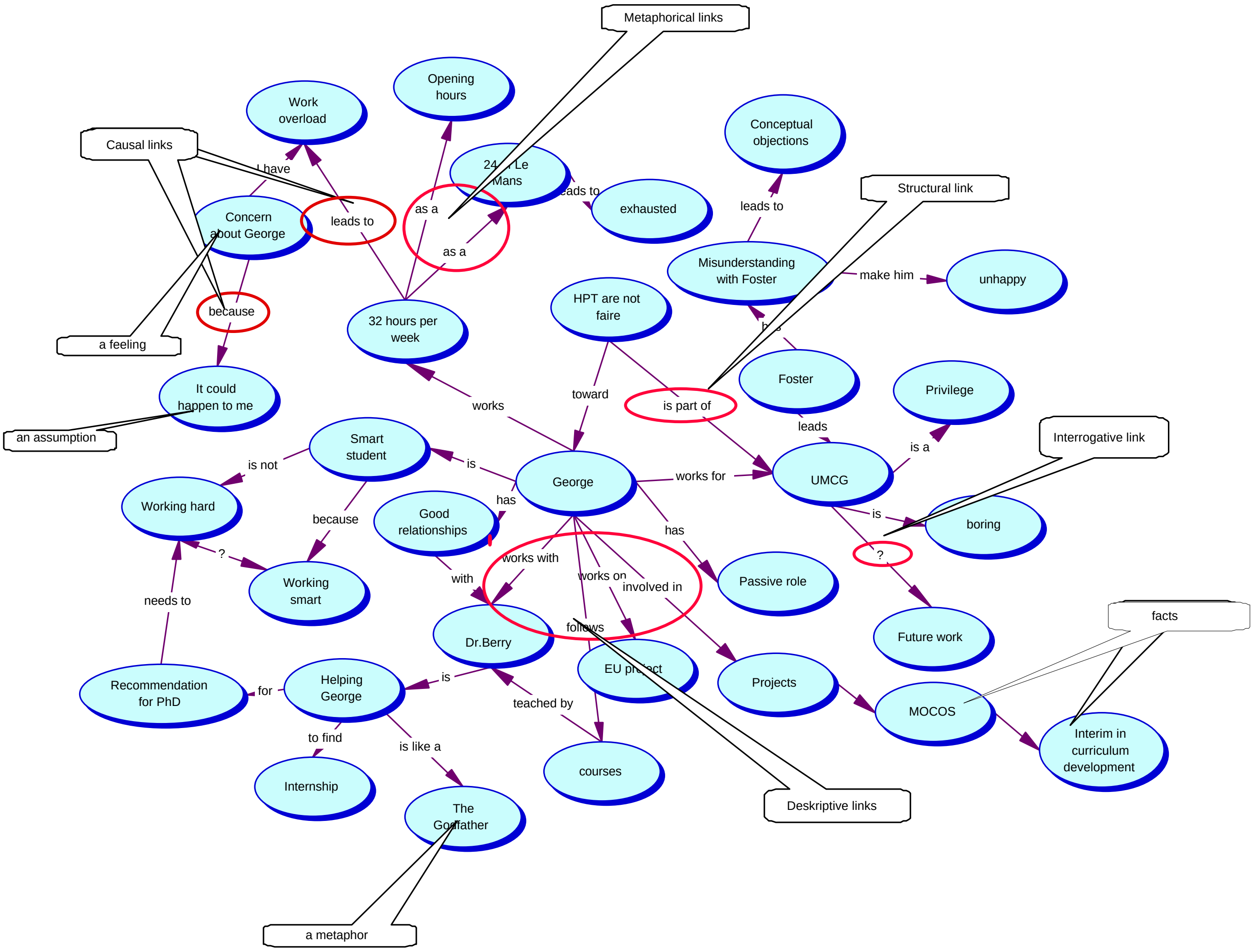
Appendix 15. Semi-structured interview

Method for solving design problems

(Questions for a semi-structured interview with experts)

1. How do you find the idea of designing a method for solving educational problems based on a combination of different mapping approaches and creative problem solving techniques? Do you see some reasons for that?
2. What do you think of the stages of the method – information collection, idea generation, idea selection and idea implementation? Is something missing? What do you add?
3. What do you think of the techniques suggested by a method? What is you favourite idea generation technique?
4. How about the labels on the links? Does it sound natural for you to make labels on the links?
5. Do you see any practical application of the method to your educational practice?

Appendix 16. Map coding scheme



Number of nodes: 32

Variety of nodes: 4 (facts, assumptions, metaphors, feelings)

Number of labels: 28

Variety of labels: 5 (structural, descriptive, causal, metaphorical, interrogative)

Appendix 17. Case description

George's Career Dilemma

Here is a case on which you can apply the mind mapping / SMILE method. You should be familiar with the situation like that. Please take some time to read the text and the instructions at the end of the case.

George, a last year student at the Faculty of Educational Sciences and Technology at University of Twente is confronted with a dilemma about his future. He is under pressure to make a decision within very short terms.

The last year's curriculum includes a field placement in a company for about 6 months. During these period students work on their final thesis while being involved in a company's projects. Normally, students visit a company with some ideas in mind what the topic and the framework of their final thesis could be. Certainly students can negotiate about that with the representatives of the company in order to balance the interests of the faculty and the company.

For some time the Faculty has been experiencing some difficulties to find places for every student. Both students and teachers consider finding a place for internship as a kind of privilege.

In this case George has taken benefit from his good professional relationships with Dr. R. Berry, a teacher in the Faculty. George has gained a reputation of one of the smartest students in the Faculty. However his performance score sheets never have been the best ones. George has been taking the courses in the selective part of the curriculum offered by Dr. Berry. Dr. Berry has involved him in one of the European projects conducted by the Faculty. Dr. R. Berry has agreed to be a mentor of George's final thesis and they have already decided about the research problem. George has to develop, from instructional design point of view, the help system of MOCOS. It is a software supporting corporate training design, developed by Adler Consulting, a well-known international consulting company. George has been finding this perspective quite promising.

Just before starting of the final project Dr. R. Berry has told George about an opportunity for a new internship and possibly for a new research problem. A new-established Human Performance Technology department of the another highly rated international consulting company - United Management Consulting Group (UMCG) has been looking for an intern with good knowledge and skills in instructional design with a perspective to work on an internal project about consulting methodology. The expected deliverable is a Performance Support System to be disseminated world wide at the branches of the company. Dr. R. Berry warn George that a competition between candidates was possible.

The leader of the HPT department of UMCG – Mr. A. Foster has formerly worked for Adler Consulting. Both R. Berry and A. Foster have known each other very well from several joint projects in the past. They meet to talk informally from time to time. George has been invited by UMCG to an interview. It has been hold by A. Foster in the presence of Dr. R. Berry. Mr. Foster has asked George to write a memo about cognitive models of consultants and he has been more than satisfied with the result. The company has wanted to hire George as an intern for as many as 40 hours per week, but Dr. Berry, has madden some objections. He has insisted George to work at least one day per week on the European project. In this negotiation George has been just a passive listener. Finally both sides, Dr. Berry and Mr. Foster have agreed upon 32 hours per week internship. During the discussion George has understood that Dr. R. Berry had lobbied in favor of MediaTech company to perform the programming part of the UMCG Management Consulting Project. There have been some rumors around the Faculty that Dr. Berry was involved non-officially in the management of MediaTech.

George has got very warm welcome from the HPT department. He has been invited by Mr. Foster and his wife, also a member of HPT department, to a private party for the members of the project.

People working in the project have been divided into sub-groups. George has been assigned to a group together with A. Foster. Every day he has been written a memo about a particular issue on request of Mr. Foster. George has been told to put everything he had written on the network public directory accessible for everyone in the company. George has recognized some of his ideas in the corporate journal articles, signed by Mr. Foster in a cooperation with other members of the department. This has not stuck him very much. He has been mostly concerned with his negative experience of failing to understand the model of consulting methodology that A. Foster had been developed. George has been told always to refer to it. He has had some conceptual objections against the model but he has been afraid to discuss them with his boss.

George has sensed also that he could contribute substantially to the instructional design part of the project, but he has been told that he had been hired as a content expert in management consulting and not as an instructional designer. George has got a confidence of an instructional designer more than of a content expert in management consulting.

However, he always has got very positive messages concerning his work. Even a roommate has told him once that there had been some indications that the management of the department had been considering the opportunity to offer George a one-year contract after his graduation.

George has expected that he would be able to present his work on the project as his final thesis, but he has been disappointed to hear by the Faculty’s management that he should chose something different. George has been involved very much in the project about methodology of consulting and he has decided to go further in this direction. He has wanted to design his own web-based performance support system concerning the methodology for consultants. Apart from Dr. R. Berry the Faculty graduation committee of George final assignment has included as well as Mr. Foster and the chief of the department where Dr. R. Berry has been affiliated.

In the middle of his internship George has got a telephone call from Dr. L. Cremmer , a faculty teacher and a colleague of Dr. R. Berry. He has invited George to an interview about a Ph.D. position. George has understood that Dr. R. Berry had recommended him to Dr. Cremmer . Neither the person, nor the topic of the Ph.D. project has been very familiar to George, but he has decided to show up himself on the interview. There have been three interviews and after that George has been told that he had been selected as a first-choice candidate. He has been told to write a proposal for the Ph.D. position. George has never told to Mr. Foster about his participation in this Ph.D. competition.

Reflecting on what has been happened, George has found himself in a rather complicated situation. He has been in the middle of his internship, he has been taking three selective courses, he has been writing a Ph.D. proposal and he has been writing his final thesis.

Now, imagine you are a friend of George. He relies very much on you to help him in finding some reasonable solutions of the situation. Using Mind Manager/SMILE Maker and applying mind mapping/SMILE method, can you provide George with some suggestions what to do?

Appendix 18. Experimental validation of the SMILE problem solving method – raw data

Students' ID	Method	L Style	Broad Perception																					Diver-gency		Convergency	Planning
			Nodes									*Links*					*Labels*									
			Total number	Variety	Facts	Opinions	Data	Personal exper.	Feelings	Hypotheses	Metaph. & anal.	Total number	Variety	One-directional	Bi-directional	Cross- Links	Variety	Descriptive	Structural	Causal	Interrogative	Remote Assoc.	Number of ideas	Variety		
1	Traditional CM Method	Doers	9	2	7	2	0	0	0	0	0	21	2	20	1	0	2	0	13	1	0	0	2	1	1	0
2			10	2	7	3	0	0	0	0	0	20	3	13	6	1	2	0	16	1	0	0	3	1	1	1
3			16	2	10	6	0	0	0	0	0	23	1	23	0	0	2	0	19	0	0	0	6	2	0	1
4			12	3	9	3	0	0	1	0	0	22	2	20	2	0	3	1	12	1	0	0	2	1	2	1
5			20	3	15	4	0	0	0	0	1	32	2	27	0	5	3	2	8	2	0	0	5	1	1	0
6			5	2	4	1	0	0	0	0	0	9	2	5	4	0	3	1	4	1	0	0	3	1	2	0
7			11	3	7	3	0	0	1	0	0	19	3	15	2	2	3	1	2	0	0	0	2	1	1	1
8			10	2	6	4	0	0	0	0	0	20	3	9	8	3	3	4	12	1	0	0	4	2	2	1
9		Thinkers	13	2	8	5	0	0	0	0	0	20	3	18	1	1	3	2	12	0	0	0	5	1	0	0
10			9	2	7	2	0	0	0	0	0	15	3	10	2	3	3	1	12	1	0	0	2	1	1	1
11			7	2	6	1	0	0	0	0	0	13	2	10	0	3	3	0	1	0	0	0	5	1	3	2
12			9	2	6	3	0	0	0	0	0	14	3	11	2	1	2	0	7	1	0	0	4	1	3	1
13			9	2	7	2	0	0	0	0	0	10	2	9	0	1	2	1	9	0	0	0	4	1	1	1
14			10	2	7	3	0	0	0	0	0	15	2	11	2	2	3	1	8	1	0	0	3	1	0	0
15			12	2	8	4	0	0	0	0	0	17	3	9	4	4	4	4	6	1	1	0	1	1	1	0
16			9	2	7	2	0	0	0	0	0	14	3	11	2	1	3	1	8	1	0	0	2	1	1	1
17	SMILE PS Method	Doers	19	7	11	2	0	2	1	1	2	24	3	17	2	5	3	5	3	2	0	3	8	1	2	1
18			13	4	5	4	0	0	2	0	2	13	1	13	0	0	5	3	3	1	1	2	4	2	1	2
19			23	6	6	3	5	2	4	2	0	29	3	22	4	3	3	3	4	1	0	0	17	4	2	1
20			9	6	3	1	2	1	1	1	0	10	3	10	1	1	3	0	2	0	1	0	9	3	1	4
21			11	3	8	0	0	0	3	0	0	11	1	11	0	0	2	2	3	1	0	0	6	1	1	4
22			19	4	8	4	0	3	3	0	1	19	1	19	0	0	4	2	12	1	0	2	10	2	4	1
23			19	3	10	0	0	5	4	0	0	19	1	19	0	0	3	2	11	2	0	0	11	2	1	3
24			11	5	5	2	0	1	1	1	1	12	2	11	0	1	2	1	0	1	0	1	7	1	2	3
25		Thinkers	10	4	5	2	0	0	2	0	1	10	1	10	0	0	3	2	1	1	0	1	12	1	4	0
26			14	5	5	4	1	0	1	3	0	14	1	14	0	0	3	3	2	2	0	0	34	2	5	2
27			46	7	22	3	2	2	5	8	4	48	2	45	0	3	5	11	14	8	4	1	30	4	3	2
28			12	4	6	3	0	2	0	1	0	11	1	11	0	0	4	1	4	1	1	0	6	2	1	1
29			17	4	6	0	4	3	4	0	0	18	2	17	0	1	3	3	6	2	0	2	7	1	2	1
30			11	4	7	2	1	0	1	0	0	11	1	11	0	0	3	2	2	1	0	0	7	1	3	0
31			18	5	9	1	3	1	2	1	1	18	1	18	0	0	4	3	5	2	1	1	16	2	3	4
32			16	4	8	2	2	1	2	1	0	19	2	18	0	1	4	4	5	2	1	1	16	2	3	1

Appendix 19. Experimental validation of the SMILE problem solving method - descriptive statistics

Broad Perception – nodes

Dependent Variable	METHOD	Learning Style	Mean	Std. Deviation	N
Fluency – Number of nodes	Traditional	Thinkers	11.6250	4.5650	8
		Doers	9.7500	1.9086	8
		Total	10.6875	3.5160	16
	SMILE	Thinkers	15.5000	5.0990	8
		Doers	18.0000	11.6741	8
		Total	16.7500	8.7977	16
	Total	Thinkers	13.5625	5.0855	16
		Doers	13.8750	9.1351	16
		Total	13.7187	7.2745	32
Flexibility – Variety of nodes	Traditional	Thinkers	2.3750	.5175	8
		Doers	2.0000	.0000	8
		Total	2.1875	.4031	16
	SMILE	Thinkers	4.7500	1.4880	8
		Doers	4.6250	1.0607	8
		Total	4.6875	1.2500	16
	Total	Thinkers	3.5625	1.6317	16
		Doers	3.3125	1.5370	16
		Total	3.4375	1.5645	32
Relative number of **Facts**	Traditional	Thinkers	70.6250	7.5202	8
		Doers	73.2500	7.9776	8
		Total	71.9375	7.6111	16
	SMILE	Thinkers	47.6250	12.0941	8
		Doers	49.3750	8.8630	8
		Total	48.5000	10.2827	16
	Total	Thinkers	59.1250	15.3531	16
		Doers	61.3125	14.7771	16
		Total	60.2188	14.8644	32
Relative number of **Opinions**	Traditional	Thinkers	27.7500	7.7598	8
		Doers	28.1250	7.9899	8
		Total	27.9375	7.6111	16
	SMILE	Thinkers	12.8750	11.7283	8
		Doers	15.0000	9.9714	8
		Total	13.9375	10.5734	16
	Total	Thinkers	20.3125	12.3002	16
		Doers	21.5625	11.0512	16
		Total	20.9375	11.5198	32
Relative number of **Data**	Traditional	Thinkers	.0000	.0000	8
		Doers	.0000	.0000	8
		Total	.0000	.0000	16
	SMILE	Thinkers	5.1250	9.4934	8
		Doers	10.7500	8.2071	8
		Total	7.9375	9.0515	16
	Total	Thinkers	2.5625	7.0045	16
		Doers	5.3750	7.8899	16
		Total	3.9688	7.4768	32
Relative number of **Personal Experience**	Traditional	Thinkers	.0000	.0000	8
		Doers	.0000	.0000	8
		Total	.0000	.0000	16
	SMILE	Thinkers	10.2500	11.1323	8
		Doers	5.0000	6.1412	8
		Total	7.6250	9.0985	16
	Total	Thinkers	5.1250	9.2655	16
		Doers	2.5000	4.9261	16
		Total	3.8125	7.4203	32

Dependent Variable	METHOD	Learning Style	Mean	Std. Deviation	N
Relative number of **Feelings**	Traditional	Thinkers	1.1350	3.1781	8
		Doers	.0000	.0000	8
		Total	.5675	2.2488	16
	SMILE	Thinkers	17.6250	5.8294	8
		Doers	11.6250	7.5202	8
		Total	14.6250	7.2007	16
	Total	Thinkers	9.3800	9.6480	16
		Doers	5.8125	7.9012	16
		Total	7.5963	8.8619	32
Relative number of **Hypotheses**	Traditional	Thinkers	.0000	.0000	8
		Doers	.0000	.0000	8
		Total	.0000	.0000	16
	SMILE	Thinkers	2.6250	2.9246	8
		Doers	8.5000	7.9462	8
		Total	5.5625	6.5317	16
	Total	Thinkers	1.3125	2.4144	16
		Doers	4.2500	6.9809	16
		Total	2.7813	5.3505	32
Relative number of **Metaphors & Analogies**	Traditional	Thinkers	.6250	1.7678	8
		Doers	.0000	.0000	8
		Total	.3125	1.2500	16
	SMILE	Thinkers	5.5000	6.1644	8
		Doers	2.8750	4.1209	8
		Total	4.1875	5.2436	16
	Total	Thinkers	3.0625	5.0526	16
		Doers	1.4375	3.1826	16
		Total	2.2500	4.2350	32

Broad Perception – links

Dependent Variable	METHOD	Learning Style	Mean	Std. Deviation	N
Fluency – Number of Links	Traditional	Thinkers	20.7500	6.2735	8
		Doers	14.7500	2.9155	8
		Total	17.7500	5.6510	16
	SMILE	Thinkers	17.1250	6.8335	8
		Doers	18.6250	12.3974	8
		Total	17.8750	9.7014	16
	Total	Thinkers	18.9375	6.6078	16
		Doers	16.6875	8.9273	16
		Total	17.8125	7.8100	32
Flexibility – Variety of Links	Traditional	Thinkers	2.2500	.7071	8
		Doers	2.6250	.5175	8
		Total	2.4375	.6292	16
	SMILE	Thinkers	1.8750	.9910	8
		Doers	1.3750	.5175	8
		Total	1.6250	.8062	16
	Total	Thinkers	2.0625	.8539	16
		Doers	2.0000	.8165	16
		Total	2.0313	.8224	32
Relative number of **One-directional Links**	Traditional	Thinkers	76.8750	19.6791	8
		Doers	76.0000	12.1302	8
		Total	76.4375	15.7986	16
	SMILE	Thinkers	92.5000	11.7959	8
		Doers	97.8750	2.9490	8
		Total	95.1875	8.7576	16
	Total	Thinkers	84.6875	17.6285	16
		Doers	86.9375	14.1538	16
		Total	85.8125	15.7673	32

Dependent Variable	METHOD	Learning Style	Mean	Std. Deviation	N
Relative number of **Bi-directional Links**	Traditional	Thinkers	16.0000	15.8925	8
		Doers	9.6250	8.1930	8
		Total	12.8125	12.6503	16
	SMILE	Thinkers	4.3750	6.5452	8
		Doers	.0000	.0000	8
		Total	2.1875	5.0096	16
	Total	Thinkers	10.1875	13.1870	16
		Doers	4.8125	7.4853	16
		Total	7.5000	10.8954	32
Relative number of **Cross-Links**	Traditional	Thinkers	5.8750	7.0799	8
		Doers	14.5000	7.1913	8
		Total	10.1875	8.2075	16
	SMILE	Thinkers	6.2500	9.4831	8
		Doers	2.8750	3.0909	8
		Total	4.5625	7.0330	16
	Total	Thinkers	6.0625	8.0868	16
		Doers	8.6875	8.0392	16
		Total	7.3750	8.0432	32

Broad Perception – Labels.

Dependent Variable	METHOD	Learning Style	Mean	Std. Deviation	N
Flexibility – Variety of Labels	Traditional	Thinkers	2.6250	.5175	8
		Doers	2.8750	.6409	8
		Total	2.7500	.5774	16
	SMILE	Thinkers	3.1250	.9910	8
		Doers	3.6250	.7440	8
		Total	3.3750	.8851	16
	Total	Thinkers	2.8750	.8062	16
		Doers	3.2500	.7746	16
		Total	3.0625	.8007	32
Relative number of **Descriptive Labels**	Traditional	Thinkers	52.5000	25.0428	8
		Doers	54.1250	25.3852	8
		Total	53.3125	24.3741	16
	SMILE	Thinkers	27.6250	22.2386	8
		Doers	24.2500	9.2698	8
		Total	25.9375	16.5508	16
	Total	Thinkers	40.0625	26.2386	16
		Doers	39.1875	24.0589	16
		Total	39.6250	24.7670	32
Relative number of **Structural Labels**	Traditional	Thinkers	5.8750	6.8752	8
		Doers	8.1250	7.5107	8
		Total	7.0000	7.0522	16
	SMILE	Thinkers	10.1250	8.5262	8
		Doers	18.2500	4.3012	8
		Total	14.1875	7.7564	16
	Total	Thinkers	8.0000	7.7974	16
		Doers	13.1875	7.8928	16
		Total	10.5938	8.1552	32
Relative number of **Causal Labels**	Traditional	Thinkers	5.3750	4.3074	8
		Doers	3.6250	2.6152	8
		Total	4.5000	3.5590	16
	SMILE	Thinkers	6.5000	3.5051	8
		Doers	8.7500	3.5757	8
		Total	7.6250	3.6125	16
	Total	Thinkers	5.9375	3.8379	16
		Doers	6.1875	4.0203	16
		Total	6.0625	3.8683	32

Dependent Variable	METHOD	Learning Style	Mean	Std. Deviation	N
Relative number of **Interrogative Labels**	Traditional	Thinkers	.0000	.0000	8
		Doers	.7500	2.1213	8
		Total	.3750	1.5000	16
	SMILE	Thinkers	2.1250	3.9438	8
		Doers	3.5000	3.9279	8
		Total	2.8125	3.8681	16
	Total	Thinkers	1.0625	2.9090	16
		Doers	2.1250	3.3640	16
		Total	1.5938	3.1404	32
Relative number of **Remote Association Labels**	Traditional	Thinkers	.0000	.0000	8
		Doers	.0000	.0000	8
		Total	.0000	.0000	16
	SMILE	Thinkers	5.5000	6.1644	8
		Doers	4.2500	4.4960	8
		Total	4.8750	5.2520	16
	Total	Thinkers	2.7500	5.0794	16
		Doers	2.1250	3.7749	16
		Total	2.4375	4.4136	32

***Divergency, Convergency and Planning*.**

Dependent Variable	METHOD	Learning Style	Mean	Std. Deviation	N
Divergency – *Number of Ideas*	Traditional	Thinkers	3.3750	1.5059	8
		Doers	3.2500	1.4880	8
		Total	3.3125	1.4477	16
	SMILE	Thinkers	9.0000	3.9279	8
		Doers	16.0000	10.6771	8
		Total	12.5000	8.5713	16
	Total	Thinkers	6.1875	4.0861	16
		Doers	9.6250	9.8784	16
		Total	7.9063	7.6384	32
Divergency *– Variety of Ideas*	Traditional	Thinkers	1.2500	.4629	8
		Doers	1.0000	.0000	8
		Total	1.1250	.3416	16
	SMILE	Thinkers	2.0000	1.0690	8
		Doers	1.8750	.9910	8
		Total	1.9375	.9979	16
	Total	Thinkers	1.6250	.8851	16
		Doers	1.4375	.8139	16
		Total	1.5312	.8418	32
Convergency	Traditional	Thinkers	1.2500	.7071	8
		Doers	1.2500	1.1650	8
		Total	1.2500	.9309	16
	SMILE	Thinkers	1.7500	1.0351	8
		Doers	3.0000	1.1952	8
		Total	2.3750	1.2583	16
	Total	Thinkers	1.5000	.8944	16
		Doers	2.1250	1.4549	16
		Total	1.8125	1.2297	32
Planning	Traditional	Thinkers	.6250	.5175	8
		Doers	.7500	.7071	8
		Total	.6875	.6021	16
	SMILE	Thinkers	2.3750	1.3025	8
		Doers	1.3750	1.3025	8
		Total	1.8750	1.3601	16
	Total	Thinkers	1.5000	1.3166	16
		Doers	1.0625	1.0626	16
		Total	1.2813	1.1977	32

Appendix 20. Styles Inventory

Styles Inventory

This styles inventory is about learning, problem solving and locus of control styles. It is designed to get some information about your preferences to the ways of learning, problem solving and learning environment organisation. There are not bad or good learning styles, problem solving styles and learning locus of control styles. They are just different. Please read the statement bellow and range them, according to your preferences. Put any name, pseudonym or code to indicate who has worked on this inventory.

Learning Styles

It is well known fact that people learn in different way or they have different learning styles. In the space bellow some statements indicative for different learning styles are given. Please check your learning styles preferences attaching a number to them. '1' is the most preferable, '4' is the least preferable.

☐ Usually, I prefer to have a good explanation what is the theoretical background of something, and why it is made in a particular way.

☐ Usually, I prefer to have some examples, cases or demonstrations and then to reflect on them in order to extract the information I need.

☐ Usually, I prefer step-by-step approach, following a well established procedures or guidelines.

☐ Usually, I prefer learning-by-doing, starting immediately to make the things.

Problem Solving Styles

People are complex in their problem solving activities but they develop, because of different reasons, more strong abilities for some of these activities. Usually, they use less energy and perform easier some of them. People have different problem solving styles. In the space bellow some statements are given, indicative for people sensitiveness for problem solving activities. Please range the statements from '1' to '4' according to the extent to which they are valid for you. '1' is the highest and '4' is the lowest extent.

☐ I am strong in collection of information.

☐ I am strong in generation of many and diverse ideas.

☐ I am strong in analysis and selection of the best idea among others.

☐ I am strong in putting ideas into practice.

Learning Locus of Control

Learning locus of control differentiates people on the extent to which they prefer well structured, or more loose learning environment. Please range the statements from ‘1’ to ‘4’ according to the extent to which they are valid for you. ‘1’ is the highest and ‘4’ is the lowest extent.

☐ I prefer to be involved in very well structured learning activities where the content is organised in the same way for everybody, and I would like to be told what to do and how to do it.

☐ I like learning environments were the instructors are organised the content in different ways, according to the individual preferences of the learners.

☐ I prefer to know what is the content to be studied, but I would like to be left to decide myself upon the way of learning.

☐ I appreciate very much the freedom to select the content and to organise it an appropriate way. I love to be responsible for both the content and the way of learning.

Name or pseudonym:

Appendix 21. The SMILE Maker Reflective Questionnaire

SMILE Maker Reflective Questionnaire

This questionnaire is aimed at facilitating your reflections on the experience you have got using SMILE Maker. There are three parts: method, learning environment, and interface. Please read each of the statements in the space bellow and try to indicate (by thick or cross) the extent to which you agree or do not agree with this statement. The number '5' means 'strongly agree', '1'- stands for 'strongly disagree'. There are not right or wrong answers. Filling in the questionnaire will take you between 5 and 10 minutes. The accuracy of the results depends on how honest you can be.

Thank you.

Method

SMILE Maker introduces ***SMILE method****. The method is supposed to support your* ***problem solving*** *activities. The statements included in this section might be indicative for the extent to which this method was useful for you.*

1. SMILE Maker provided me with a support how to use the graphical editor of the tool.	5 SA	4	3	2	1 SD
2. SMILE Maker did not provide me with a support for the process of problem solving.	5 SA	4	3	2	1 SD
3. I was able to get a clear picture what the problem is about.	5 SA	4	3	2	1 SD
4. I was able to get a broad picture of the problem situation.	5 SA	4	3	2	1 SD
5. I was able to express everything I knew and felt about the problem situation.	5 SA	4	3	2	1 SD
6. It was easy to represent the problem situation in a comprehensive way.	5 SA	4	3	2	1 SD
7. It was easy to simplify the complexity of the problem situation.	5 SA	4	3	2	1 SD
8. I was able to see very clear the relationships between the components of the problem situation.	5 SA	4	3	2	1 SD
9. I was able to link the components of the problem situation in the way I wanted.	5 SA	4	3	2	1 SD
10. I was able to generate many ideas.	5 SA	4	3	2	1 SD
11. I had a feeling that I came up to some non-conventional ideas.	5 SA	4	3	2	1 SD

12. I was able to change the way I was looking at the problem situation. — 5 (SA) 4 3 2 1 (SD)

13. I was able to reflect critically on my thoughts and ideas. — 5 (SA) 4 3 2 1 (SD)

14. I was able to select the best candidate among the alternative solutions. — 5 (SA) 4 3 2 1 (SD)

15. I could not develop a plan for implementing the solution (s). — 5 (SA) 4 3 2 1 (SD)

16. When representing the problem situation I used different types of items:

• Proved facts and data/statistics	5	4	3	2	1
• Metaphors	5	4	3	2	1
• Personal opinions	5	4	3	2	1
• Feelings	5	4	3	2	1
• Intuition	5	4	3	2	1
• Other (Please indicate what if any): ……………………….. ………………………………………	5	4	3	2	1
	SA				SD

17. The fixed format of the method restricted me to represent the situation in a way I would like. — 5 (SA) 4 3 2 1 (SD)

18. I used different kind of links to represent the relationships between the components of the situation:

• Descriptive	5	4	3	2	1
• Causal	5	4	3	2	1
• Structural	5	4	3	2	1
• Metaphorical	5	4	3	2	1
• Other (Please indicate what if any): ……………………….. ………………………………………	5	4	3	2	1
	SA				SD

19. The method facilitated the flow of my associations and ideas. — 5 (SA) 4 3 2 1 (SD)

20. I did not find enough ***support*** for:

• Describing the problem situation	5	4	3	2	1
• Analyzing the problem situation	5	4	3	2	1
• Producing a large scope of solutions	5	4	3	2	1
• Generating original solutions	5	4	3	2	1
• Changing the perspective of looking at the problem	5	4	3	2	1
• Selecting the best candidate among the eventual solutions	5	4	3	2	1

• Predicting the important factors that could affect the	5	4	3	2	1
• Planning what should be done to implement the solution	5 SA	4	3	2	1 SD
21. I was able to solve the case in a systematic way.	5 SA	4	3	2	1 SD
22. The SMILE method of problem solving confused me.	5 SA	4	3	2	1 SD
23. I would rather prefer to use other methods for problem solving than SMILE	5 SA	4	3	2	1 SD
24. I should blame the graphical editor of the tool for frustration I got than the method itself.	5 SA	4	3	2	1 SD
25. I did not find enough support how to apply the method	5 SA	4	3	2	1 SD
26. I would like to use the tool in my future projects	5 SA	4	3	2	1 SD

Learning Environment

SMILE Maker tool proposes a learning environment where you can study what the SMILE method is about and how it can be applied in different situations. The statements in this section might be indicative for the way you perceive this learning environment and how much it was useful for studying the method.

The number '5' means 'strongly agree', '1' - stands for 'strongly disagree'.

1. SMILE Maker supported me how to use the graphical editor of the tool.	5 SA	4	3	2	1 SD
2. SMILE Maker did not supported me how to apply SMILE problem solving method.	5 SA	4	3	2	1 SD
3. The learning environment provided me with background information about SMILE problem solving method.	5 SA	4	3	2	1 SD
4. I found some good examples how SMILE problem solving method could be applied.	5 SA	4	3	2	1 SD
5. I was happy to find enough guidelines how to proceed when using the method.	5 SA	4	3	2	1 SD
6. I liked the idea of having an opportunity immediately to start practising the method.	5 SA	4	3	2	1 SD
7. I was able to select learning approach that fits mostly to my learning preferences.	5 SA	4	3	2	1 SD

8. I had an opportunity to check my learning preferences. 5 (SA) 4 3 2 1 (SD)

9. It was not easy to understand what the SMILE method is about. 5 (SA) 4 3 2 1 (SD)

10. The self-study approach was not sufficient for mastering the method. 5 (SA) 4 3 2 1 (SD)

Interface

This section includes some statements concerning how you might perceive the interface of SMILE Maker. '5' means 'strongly agree', '1' - stands for 'strongly disagree'.

1. I found SMILE Maker an attractive tool. 5 (SA) 4 3 2 1 (SD)

2. I had difficulties to find the information I wanted. 5 (SA) 4 3 2 1 (SD)

3. It took me too much time to understand how the graphical editor works 5 (SA) 4 3 2 1 (SD)

4. The navigation through the tool was easy. 5 (SA) 4 3 2 1 (SD)

5. Any time I knew where I am and where I should go. 5 (SA) 4 3 2 1 (SD)

6. Opening for the first time the tool I was able to use it directly. 5 (SA) 4 3 2 1 (SD)

Name (pseudonym): …………………………………………………………………………………….

Scale	Sub-scale	Questions
Method	Eliciting	3, 4, 5, 16, 18, 20 c*, 20 d*, 20 e*
	Creating	10, 11, 12, 15*, 19,
	Reflecting	7, 8, 13, 14, 20 b*, 20 f*, 20 g*
	Representing	6, 9, 17*, 20 a*, 20 h*
	Support for the method	2*, 21, 22*, 23*, 25*, 26
	Support of the graphical editor	1, 24*
Learning Environment	Graphical editor – learning support	1
	Problem Solving Method – learning support	2
	Explanation	3
	Examples	4
	Procedures	5
	Practice	6
	Individual approach	7, 8
	Learnability	9*, 10*
Interface	Attractiveness	1
	Interface of the graphical editor	3*
	Affordance	6
	Navigation	2*, 4, 5

* The question is counter indicative

Appendix 22. Instruction

Dear All,

This is to invite you to join the research team and to assist in figuring out what constitutes an effective tool for problem solving. You will be able to apply your expertise in evaluating software that is supposed to facilitate people when ill-structured situations occur. This software is based upon mapping - a particular technique for creative problem solving. May be it does not speak very much to you at this moment but we hope you will realize quickly how friendly and intuitive it is. We will be in help about this. You will get the software and you will be able to use it in your future projects if you want to do so. In the space bellow some estimation about commitments and timing are given:

1. We will provide you with a short introduction about the background and the purposes of the research (30 min.)
2. There will be a short training how the software works (30 min)
3. You will be asked to fill in a Style Inventory. This is about your problem solving and learning styles. What you have to do is to identify the extent to which you are agreed to the statements. (no more than 5 min.)
4. You will be introduced to a real life case with the idea to use the software and the method in order to analyze the situation and to suggest some solutions. To make easier for you, the case has nothing to do with any particular subject matter knowledge and skills developed in the school or university. Certainly, out of this research context, in future terms, you will be able to apply the software either on course assignments or projects related to particular knowledge and skills. (Approximately 3 hours. Ideally you will be able to work at home. You will able to install the program.)
5. At the end you will be asked to fill in a questionnaire capturing your expert's reflections on working with the software. Again, as it is with Style Inventory, you should indicate the extent to which you are agreed with the statements about the method, learning environment and the interface of the tool (10-15 min)
6. Every one of you will be provided with a disc in order to save the deliverables that should be produced. Save each map you have drown. Please give any indication (name, pseudonym, code) the same as on your Style Inventory and Reflective Questionnaire.

We appreciate very much your willingness to take part in this research.

Sincerely yours,

Slavi Stoyanov

Appendix 23. Experimental validation of the SMILE Maker Tool. Map production and case solution - raw data

	Case solution – experts' evaluation		
ID	**Coder 1**	**Coder 2**	**Mean**
1	7.00	9.00	8.00
2	8.00	8.00	8.00
3	7.00	9.00	8.00
4	8.00	6.00	7.00
5	7.00	7.00	7.00
6	8.00	9.00	8.50
7	8.00	9.00	8.50
8	9.00	9.00	9.00
9	9.00	9.00	9.00
10	9.00	9.00	9.00
11	9.00	9.00	9.00
12	9.00	7.00	8.00
13	7.00	9.00	8.00
14	5.00	5.00	5.00
15	5.00	5.00	5.00
16	4.00	6.00	5.00
17	5.00	5.00	5.00
18	9.00	9.00	9.00
19	9.00	9.00	9.00
20	6.00	8.00	7.00
21	7.00	7.00	7.00
22	.00	.00	.00
23	7.00	8.00	7.50
24	8.00	7.00	7.50
25	10.00	9.00	9.50
26	10.00	9.00	9.50
27	10.00	8.00	9.00
28	9.00	9.00	9.00
29	5.00	5.00	5.00
30	8.00	6.00	7.00
31	6.00	8.00	7.00
32	7.00	7.00	7.00
33	.00	.00	.00
34	.00	.00	.00
35	8.00	6.00	7.00
36	7.00	7.00	7.00
37	7.00	9.00	8.00
38	7.00	7.00	7.00
39	6.00	8.00	7.00
40	7.00	7.00	7.00
41	6.00	8.00	7.00
42	.00	.00	.00
43	7.00	7.00	7.00
44	.00	.00	.00
45	.00	.00	.00
46	8.00	9.00	9.50
47	5.00	5.00	5.00

					Broad Perception							Divergency			Converg.		Planning				
	Group	***Learning style***	***P S Style***	***L L Control***	***Nodes-total***	***Nodes-fluency***	***Nodes-variety***	***Nodes-flexibility***	***Labels-total***	***Labels-variety***	***Labels-flexibility***	***Number Ideas***	***Diversity ideas***	***Originality ideas***	***Select. criteria***	***Selection***	***Posit. factors***	***Negat. factors***	***Preventive act.***	***Steps***	***Comprehensiv.***
1.	1	1	3	1	23	3.5	5	3	20	3	0	0	0	0	0	0	0	3	0	0	0
2.	1	2	3	1	23	3.5	3	3	20	3	0	0	0	0	0	0	2	1	0	0	0
3.	1	3	3	2	8	1	3	1	4	2	1	0	0	0	2	0	0	3	0	0	0
4.	1	2	1	1	25	4	3	5	23	3	3	18	4	3	0	0	2	2	2	2	2
5.	1	2	1	1	25	4	5	4	23	3	3	18	4	3	4	0	2	2	0	2	2
6.	1	2	3	1	23	3.5	3	3	20	3	0	0	0	0	2	0	3	2	1	2	2
7.	1	1	3	1	23	3.5	4	3	20	3	0	0	5	0	0	0	1	0	1	2	3
8.	1	2	4	2	16	3	3	3	15	2	2	1	1	1	0	2	1	0	1	1	1
9.	1	2	4	2	16	3	3	3	15	2	2	1	1	1	2	2	3	3	0	1	1
10.	1	3	2	2	15	2	4	3	4	1	1	2	2	1	2	2	0	2	0	0	1
11.	1	3	3	1	11	2	5	4	12	2	2	6	2	2	3	2	0	3	1	2	2
12.	1	3	3	1	11	2	3	4	12	2	2	6	2	2	3	2	2	0	1	2	2
13.	1	1	2	1	32	4	5	1	10	2	2	6	3	2	0	2	0	1	1	4	3
14.	1	2	3	2	8	2	1	1	3	2	1	8	3	3	1	3	2	2	1	2	1
15.	1	3	2	1	8	2	5	4	3	2	1	8	3	3	1	3	0	2	0	3	1
16.	1	3	2	1	8	2	3	1	3	2	1	8	3	3	1	3	1	2	0	2	1
17.	1	1	2	1	32	4	5	5	10	2	2	6	3	2	3	3	1	2	1	4	3
18.	1	4	4	1	16	3	4	3	24	3	4	8	4	3	0	4	1	4.5	0	0	0
19.	1	4	4	1	16	3	4	3	24	3	4	8	4	3	4	4	0	1	1	0	0
20.	1	4	4	2	15	4	3	3	16	3	3	12	5	4	0	4	0	0	2	5	3
21.	1	4	4	2	15	4	3	3	16	3	3	12	5	4	4	4	0	1	1	5	3
22.	1	1	1	2	12	2.5	4	4	17	3	4	5	4	4	0	5	1	2	1	1	1
23.	1	1	1	2	12	2.5	3	4	17	3	4	5	4	4	3	5	3	0	2	1	1
24.	1	3	2	1	21	4	4	3	23	2	2	19	4	4	5	5	3	4.5	4	2	2.5
25.	1	3	2	1	21	4	4	3	23	2	2	19	4	4	5	5	3	0	4	2	2.5
26.	1	3	2	1	21	4	4	3	23	2	2	19	4	4	5	5	3	1	4	2	2.5
27.	2	1	2	1	8	1	1	1	4	2	1	0	0	0	0	0	0	0	0	0	0
28.	2	1	3	1	23	3.5	1	3	20	3	0	0	0	0	0	0	0	0	0	0	0
29.	2	2	3	1	23	3.5	3	3	20	3	0	0	0	0	1	0	0	0	0	0	0
30.	2	3	1	2	8	1	4	1	4	2	1	0	0	0	0	0	0	0	0	0	0
31.	2	3	3	1	8	1	1	1	4	2	1	0	0	0	0	0	0	0	0	0	0
32.	2	3	3	2	8	1	5	1	4	2	1	0	0	0	2	0	0	0	0	0	0
33.	2	3	4	2	8	1	4	1	4	2	1	0	0	0	0	0	0	1	0	0	0

					Broad Perception							**Divergency**			**Converg.**		**Planning**				
	Group	***Learning style***	***P S Style***	***L L Control***	***Nodes-total***	***Nodes-fluency***	***Nodes-variety***	***Nodes-flexibility***	***Labels-total***	***Labels-variety***	***Labels-flexibility***	***Number Ideas***	***Diversity ideas***	***Originality ideas***	***Select. criteria***	***Selection***	***Posit. factors***	***Negat. factors***	***Preventive act.***	***Steps***	***Comprehensiv.***
34.	2	2	1	1	25	4	3	4	23	3	3	18	4	3	0	0	2	2	1	2	2
35.	2	1	2	2	32	4	4	5	10	2	2	6	3	2	0	0	3	1	1	4	3
36.	2	1	2	2	15	2	4	3	4	1	1	2	2	1	0	2	0	2	0	0	1
37.	2	1	2	1	15	2	1	3	4	1	1	2	2	1	2	2	0	2	1	0	1
38.	2	3	1	2	15	2	4	3	4	1	1	2	2	1	2	2	0	2	1	0	1
39.	2	3	2	1	15	2	1	3	4	1	1	2	2	1	2	2	0	2	1	0	1
40.	2	4	2	2	15	2	5	3	4	1	1	2	2	1	2	2	0	2	1	0	1
41.	2	4	4	2	15	2	4	3	4	1	1	2	2	1	2	2	0	1	1	0	1
42.	2	2	1	2	8	2	3	1	3	2	1	8	3	3	1	3	2	2	0	2	1
43.	2	2	3	1	8	2	3	1	3	2	1	8	3	3	1	3	2	2	0	2	1
44.	2	2	3	2	8	2	3	1	3	2	1	8	3	3	1	3	2	1	1	2	1
45.	2	2	4	2	8	2	3	1	3	2	1	8	3	3	0	3	2	0	0	2	1
46.	2	4	4	1	16	3	4	3	24	3	4	8	4	3	4	4	0	0	0	0	0
47.	2	4	4	2	15	4	3	3	16	3	3	12	5	4	0	4	0	1	2	5	3

Coding:

Group: 1 – SMILE (experimental)
2 – MM (control)

Learning Style: 1 – Explanation
2 – Examples
3 – Procedures
4 – Practice

Problem Solving Style: 1 – Seeker
2 – Diverger
3 – Converger
4 – Implementer

Learning Locus of Control: 1 – External
2 – Internal

Appendix 24. Experimental validation of the SMILE Maker Tool. Reflective Questionnaire - raw data

					Method						**Learning Environment**								**Interface**			
	Group	***Learning Style***	***PS Style***	***L L Control***	***Eliciting***	***Creating***	***Reflecting.***	***Representing***	***Support-Method***	***Support-Gr.Ed.***	***Graphical Edit.***	***PS Method***	***Explanation***	***Examples***	***Procedures***	***Practice***	***Individual Appr.***	***Learnability***	***Attractiveness***	***Graphical Editor***	***Affordance***	***Navigation***
1.	1	3	2	1	41	21	24	15	23	9	4	4	2	4	4	3	7	8	4	4	4	14
2.	1	3	2	1	52	25	33	21	22	10	5	5	2	2	2	4	10	6	5	5	1	7
3.	1	3	2	1	45	25	26	14	20	9	4	5	5	4	5	5	10	7	4	3	3	8
4.	1	3	2	1	36	20	22	17	19	5	3	3	4	4	4	5	6	5	4	2	2	7
5.	1	3	2	1	42	23	22	18	20	8	4	2	4	4	3	3	6	7	4	3	3	10
6.	1	3	3	1	59	27	18	17	15	7	4	3	4	3	4	4	6	5	3	3	2	9
7.	1	3	3	1	56	34	35	14	29	10	5	5	4	3	3	2	8	8	5	4	4	11
8.	1	4	4	1	23	18	24	15	27	7	4	5	5	5	3	5	8	5	4	5	1	11
9.	1	4	4	1	36	26	25	18	27	9	4	4	5	4	4	4	6	8	5	4	3	10
10.	1	2	1	1	41	28	29	13	25	9	4	5	3	4	4	5	9	9	5	4	4	13
11.	1	2	1	1	41	21	24	15	23	9	4	4	5	5	4	5	7	8	4	4	4	14
12.	1	1	2	1	52	25	33	15	22	10	5	5	2	2	5	4	10	6	5	5	1	7
13.	1	1	2	1	45	25	26	14	20	9	4	5	3	3	4	5	10	7	4	3	3	8
14.	1	1	3	1	36	20	22	17	19	5	5	3	3	4	4	4	6	5	4	2	2	7
15.	1	1	3	1	42	23	22	12	20	8	4	2	2	2	5	3	6	7	4	3	3	10
16.	1	2	3	1	44	27	18	17	15	7	4	3	1	2	4	3	6	5	4	3	2	9
17.	1	2	3	1	39	34	35	14	29	7	3	5	2	4	4	3	8	8	5	4	4	11
18.	1	1	1	2	23	18	24	15	27	7	4	5	2	2	4	4	8	5	4	5	1	11
19.	1	1	1	2	36	26	25	18	27	9	4	4	5	4	5	5	6	8	5	4	3	10
20.	1	3	2	2	41	28	29	14	20	9	5	5	4	4	4	5	9	9	5	4	4	13
21.	1	2	3	2	34	10	11	13	15	9	4	1	4	3	3	3	4	2	5	4	3	12
22.	1	3	3	2	48	12	12	15	12	10	5	1	4	3	4	4	4	3	4	4	2	14
23.	1	2	4	2	41	21	24	15	23	9	4	4	4	3	3	2	7	8	4	4	5	12
24.	1	2	4	2	36	21	24	15	23	9	4	4	5	5	5	5	7	8	4	4	2	10
25.	1	4	4	2	48	25	33	12	22	10	3	5	5	4	4	4	10	6	5	5	1	6
26.	1	4	4	2	45	25	26	14	20	8	4	5	3	4	4	5	10	7	4	4	3	8
27.	2	4	4	1	33	17	16	9	15	6	2	2	2	5	4	4	5	3	5	4	1	9
28.	2	2	1	1	35	19	19	13	17	4	3	2	2	2	1	3	7	4	4	2	2	6
29.	2	1	3	1	33	29	25	11	20	6	5	5	3	3	4	3	4	8	5	5	2	7
30.	2	1	2	1	34	10	11	13	11	9	5	1	3	4	4	4	2	2	5	4	5	13
31.	2	3	2	1	32	12	12	15	12	10	5	1	5	2	1	3	2	3	5	4	3	14

					Method						Learning Environment								Interface			
	Group	***Learning Style***	***PS Style***	***L L Control***	***Eliciting***	***Creating***	***Reflecting.***	***Representing***	***Support-Method***	***Support-Gr.Ed.***	***Graphical Edit.***	***PS Method***	***Explanation***	***Examples***	***Procedures***	***Practice***	***Individual Appr.***	***Learnability***	***Attractiveness***	***Graphical Editor***	***Affordance***	***Navigation***
32.	2	2	3	1	33	17	18	9	15	9	5	2	4	2	1	3	5	3	5	4	1	9
33.	2	1	2	1	35	19	19	13	18	11	2	2	4	4	4	3	7	4	4	2	2	6
34.	2	3	3	1	41	29	25	18	20	6	5	5	2	2	5	4	4	8	5	5	2	7
35.	2	2	1	2	34	10	14	13	11	9	3	1	3	4	2	5	8	3	5	4	5	13
36.	2	3	1	2	32	12	15	15	12	10	4	1	3	4	4	5	6	3	4	4	3	14
37.	2	1	2	2	54	34	35	14	29	10	4	5	2	3	3	3	8	8	5	4	2	11
38.	2	4	2	2	29	18	24	15	27	8	4	5	2	3	4	4	8	5	4	5	3	11
39.	2	2	3	2	36	26	25	18	27	9	5	4	3	3	4	2	7	8	4	4	3	10
40.	2	4	4	2	52	17	16	19	15	10	5	2	3	2	5	5	4	6	4	4	4	12
41.	2	2	4	2	34	17	16	14	15	8	4	2	2	3	4	4	3	7	5	4	3	14
42.	2	3	1	2	33	17	16	12	15	6	4	2	3	4	4	5	5	4	5	4	2	9
43.	2	1	2	2	35	19	19	13	22	6	4	2	5	2	4	5	7	4	4	2	4	10
44.	2	3	3	2	48	21	25	11	20	6	4	5	2	2	1	4	8	4	5	4	2	9
45.	2	3	4	2	35	19	19	13	22	5	4	2	3	3	4	5	7	5	4	2	2	11
46.	2	4	4	2	33	23	25	11	20	7	5	5	3	4	4	4	5	8	5	5	2	7
47.	2	2	3	1	51	27	25	11	20	8	5	5	1	2	1	3	8	7	4	5	2	7

Coding:

Group: 1 – SMILE (experimental)
2 – MM (control)

Learning Style: 1 – Explanation
2 – Examples
3 – Procedures
4 – Practice

Problem Solving Style: 1 – Seeker
2 – Diverger
3 – Converger
4 – Implementer

Learning Locus of Control: 1 – External
2 – Internal

Appendix 25. Experimental validation of the SMILE Maker Tool - descriptive statistics

Map production

Broad Perception

Dependent Variables		N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Total number of nodes	SMILE	26	17.5385	6.9985	1.3725	8.00	32.00
	MM (control)	21	14.0952	6.8623	1.4975	8.00	32.00
	Total	47	16.0000	7.0772	1.0323	8.00	32.00
Fluency of nodes	SMILE	26	3.0769	.9021	.1769	1.00	4.00
	MM (control)	21	2.2381	1.0322	.2252	1.00	4.00
	Total	47	2.7021	1.0408	.1518	1.00	4.00
Variety of nodes	SMILE	26	3.6923	.9703	.1903	1.00	5.00
	MM (control)	21	3.0476	1.3220	.2885	1.00	5.00
	Total	47	3.4043	1.1732	.1711	1.00	5.00
Flexibility of nodes	SMILE	26	3.0769	1.0926	.2143	1.00	5.00
	MM (control)	21	2.2857	1.2306	.2685	1.00	5.00
	Total	47	2.7234	1.2105	.1766	1.00	5.00
Total number of labels	SMILE	26	15.3846	7.2943	1.4305	3.00	24.00
	MM (control)	21	8.0476	7.4597	1.6278	3.00	24.00
	Total	47	12.1064	8.1674	1.1913	3.00	24.00
Variety of labels	SMILE	26	2.4231	.5778	.1133	1.00	3.00
	MM (control)	21	1.9524	.7400	.1615	1.00	3.00
	Total	47	2.2128	.6896	.1006	1.00	3.00
Flexibility of labels	SMILE	26	1.9615	1.2800	.2510	.00	4.00
	MM (control)	21	1.2857	.9562	.2087	.00	4.00
	Total	47	1.6596	1.1846	.1728	.00	4.00

Divergency

Dependent Variables		N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Total number of ideas	SMILE	26	7.5000	6.5620	1.2869	.00	19.00
	MM (control)	21	4.1905	4.8951	1.0682	.00	18.00
	Total	47	6.0213	6.0487	.8823	.00	19.00
Diversity of ideas	SMILE	26	2.8462	1.6418	.3220	.00	5.00
	MM (control)	21	1.9048	1.5781	.3444	.00	5.00
	Total	47	2.4255	1.6648	.2428	.00	5.00
Originality of ideas	SMILE	26	2.3077	1.4905	.2923	.00	4.00
	MM (control)	21	1.4286	1.3628	.2974	.00	4.00
	Total	47	1.9149	1.4866	.2168	.00	4.00

Convergency

Dependent Variables		N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Selection criteria	SMILE	26	1.9231	1.8094	.3548	.00	5.00
	MM (control)	21	.9524	1.1170	.2437	.00	4.00
	Total	47	1.4894	1.5999	.2334	.00	5.00
Selection	SMILE	26	2.5000	1.8601	.3648	.00	5.00
	MM (control)	21	1.5238	1.4703	.3209	.00	4.00
	Total	47	2.0638	1.7496	.2552	.00	5.00

Planning							
Dependent Variables		**N**	**Mean**	**Std. Deviation**	**Std. Error**	**Minimum**	**Maximum**
Plan positive factors	SMILE	26	1.3077	1.1923	.2338	.00	3.00
	MM (control)	21	.6190	1.0235	.2234	.00	3.00
	Total	47	1.0000	1.1610	.1693	.00	3.00
Plan negative factors	SMILE	26	1.6923	1.3121	.2573	.00	4.50
	MM (control)	21	1.0000	.8944	.1952	.00	2.00
	Total	47	1.3830	1.1851	.1729	.00	4.50
Preventive actions	SMILE	26	1.1154	1.2434	.2439	.00	4.00
	MM (control)	21	.4762	.6016	.1313	.00	2.00
	Total	47	.8298	1.0492	.1530	.00	4.00
Planning steps	SMILE	26	1.8077	1.4702	.2883	.00	5.00
	MM (control)	21	.9048	1.4800	.3230	.00	5.00
	Total	47	1.4043	1.5274	.2228	.00	5.00
Comprehensiveness	SMILE	26	1.5577	1.0708	.2100	.00	3.00
	MM (control)	21	.8571	.9103	.1986	.00	3.00
	Total	47	1.2447	1.0523	.1535	.00	3.00

Reflective Questionnaire

Sub-scale Method							
Dependent Variables		**N**	**Mean**	**Std. Deviation**	**Std. Error**	**Minimum**	**Maximum**
Knowledge Eliciting	SMILE	26	41.6154	8.4004	1.6474	23.00	59.00
	MM (control)	21	37.2381	7.3614	1.6064	29.00	54.00
	Total	47	39.6596	8.1701	1.1917	23.00	59.00
Knowledge Creating	SMILE	26	23.3846	5.4264	1.0642	10.00	34.00
	MM (control)	21	19.6190	6.4457	1.4066	10.00	34.00
	Total	47	21.7021	6.1358	.8950	10.00	34.00
Knowledge Reflecting	SMILE	26	24.8462	6.1037	1.1970	11.00	35.00
	MM (control)	21	19.9524	5.7834	1.2620	11.00	35.00
	Total	47	22.6596	6.3905	.9321	11.00	35.00
Knowledge Representing	SMILE	26	15.2692	2.0892	.4097	12.00	21.00
	MM (control)	21	13.3333	2.7080	.5909	9.00	19.00
	Total	47	14.4043	2.5509	.3721	9.00	21.00
Support - Method	SMILE	26	21.6923	4.4611	.8749	12.00	29.00
	MM (control)	21	18.2381	5.2431	1.1441	11.00	29.00
	Total	47	20.1489	5.0776	.7406	11.00	29.00
Support – Graph. Ed.	SMILE	26	8.3846	1.4164	.2778	5.00	10.00
	MM (control)	21	7.7619	1.9724	.4304	4.00	11.00
	Total	47	8.1064	1.6970	.2475	4.00	11.00

Sub-scale Learning environment							
Dependent Variables		**N**	**Mean**	**Std. Deviation**	**Std. Error**	**Minimum**	**Maximum**
Explanation	SMILE	26	3.5385	1.2403	.2433	1.00	5.00
	MM (control)	21	2.8571	1.0142	.2213	1.00	5.00
	Total	47	3.2340	1.1835	.1726	1.00	5.00
Examples	SMILE	26	3.5000	.9487	.1861	2.00	5.00
	MM (control)	21	3.0000	.9487	.2070	2.00	5.00
	Total	47	3.2766	.9714	.1417	2.00	5.00
Procedures	SMILE	26	3.9231	.7442	.1460	2.00	5.00
	MM (control)	21	3.2381	1.4108	.3079	1.00	5.00
	Total	47	3.6170	1.1335	.1653	1.00	5.00

Sub-scale Learning environment							
Dependent Variables		**N**	**Mean**	**Std. Deviation**	**Std. Error**	**Minimum**	**Maximum**
Practice	SMILE	26	4.0000	.9798	.1922	2.00	5.00
	MM (control)	21	3.8571	.9103	.1986	2.00	5.00
	Total	47	3.9362	.9419	.1374	2.00	5.00
Individual Approach	SMILE	26	7.4615	1.8597	.3647	4.00	10.00
	MM (control)	21	5.7143	2.0036	.4372	2.00	8.00
	Total	47	6.6809	2.0966	.3058	2.00	10.00
Learnability	SMILE	26	6.5385	1.7716	.3474	2.00	9.00
	MM (control)	21	5.0952	2.0953	.4572	2.00	8.00
	Total	47	5.8936	2.0348	.2968	2.00	9.00
Support for Method	SMILE	26	3.9231	1.2938	.2537	1.00	5.00
	MM (control)	21	2.9048	1.6403	.3579	1.00	5.00
	Total	47	3.4681	1.5301	.2232	1.00	5.00
Support for Graphical Editor	SMILE	26	4.1154	.5883	.1154	3.00	5.00
	MM (control)	21	4.1429	.9636	.2103	2.00	5.00
	Total	47	4.1277	.7694	.1122	2.00	5.00

Sub-scale Interface							
Dependent Variables		**N**	**Mean**	**Std. Deviation**	**Std. Error**	**Minimum**	**Maximum**
Attractiveness	SMILE	26	4.3462	.5616	.1101	3.00	5.00
	MM (control)	21	4.5714	.5071	.1107	4.00	5.00
	Total	47	4.4468	.5441	7.936	3.00	5.00
Graphical editor	SMILE	26	3.8077	.8494	.1666	2.00	5.00
	MM (control)	21	3.8571	1.0142	.2213	2.00	5.00
	Total	47	3.8298	.9165	.1337	2.00	5.00
Affordance	SMILE	26	2.6923	1.1582	.2272	1.00	5.00
	MM (control)	21	2.6190	1.1170	.2437	1.00	5.00
	Total	47	2.6596	1.1282	.1646	1.00	5.00
Navigation	SMILE	26	10.0769	2.3987	.4704	6.00	14.00
	MM (control)	21	9.9524	2.6921	.5875	6.00	14.00
	Total	47	10.0213	2.5064	.3656	6.00	14.00
Interface total	SMILE	26	20.9615	3.5607	.6983	15.00	26.00
	MM (control)	21	20.8095	3.5584	.7765	14.00	27.00
	Total	47	20.8936	3.5216	.5137	14.00	27.00

Appendix 26. Experimental validation of the SMILE Maker Tool – regression analysis

Map production

Broad Perception – Regression analysis: coefficients

Dependent Variables	Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
Total number of nodes	1	(Constant)	20.982	3.114		6.737	.000
		Group	-3.443	2.036	-.244	-1.691	.098
	2	(Constant)	24.205	4.051		5.975	.000
		Group	-3.497	2.024	-.248	-1.727	.091
		P S Style	-1.212	.983	-.177	-1.234	.224
	3	(Constant)	27.126	4.136		6.558	.000
		Group	-3.445	1.949	-.245	-1.768	.084
		P S Style	-.320	1.035	-.047	-.309	.759
		Learning Style	-2.189	1.033	-.321	-2.119	.040
	4	(Constant)	31.156	4.325		7.203	.000
		Group	-2.449	1.911	-.174	-1.282	.207
		P S Style	-.174	.990	-.025	-.176	.861
		Learning Style	-1.978	.991	-.290	-1.997	.052
		L L Control	-4.399	1.929	-.312	-2.280	.028
Fluency of nodes	1	(Constant)	3.916	.432		9.067	.000
		Group	-.839	.282	-.405	-2.972	.005
	2	(Constant)	3.920	.571		6.861	.000
		Group	-.839	.286	-.405	-2.938	.005
		P S Style	-1.783	.139	-.002	-.013	.990
	3	(Constant)	4.097	.608		6.740	.000
		Group	-.836	.286	-.404	-2.919	.006
		P S Style	5.202	.152	.052	.342	.734
		Learning Style	-.132	.152	-.132	-.870	.389
	4	(Constant)	4.545	.652		6.969	.000
		Group	-.725	.288	-.350	-2.517	.016
		P S Style	6.827	.149	.068	.457	.650
		Learning Style	-.108	.149	-.108	-.726	.472
		L L Control	-.489	.291	-.236	-1.683	.100
Variety of nodes	1	(Constant)	4.337	.512		8.475	.000
		Group	-.645	.334	-.276	-1.927	.060
	2	(Constant)	5.235	.644		8.132	.000
		Group	-.660	.322	-.282	-2.050	.046
		P S Style	-.338	.156	-.298	-2.163	.036
	3	(Constant)	5.211	.691		7.546	.000
		Group	-.660	.325	-.283	-2.028	.049
		P S Style	-.345	.173	-.304	-1.996	.052
		Learning Style	1.792	.173	.016	.104	.918
	4	(Constant)	5.632	.749		7.520	.000
		Group	-.556	.331	-.238	-1.680	.100
		P S Style	-.330	.171	-.291	-1.923	.061
		Learning Style	4.003	.172	.035	.233	.817
		L L Control	-.459	.334	-.197	-1.375	.176
Flexibility of nodes	1	(Constant)	3.868	.519		7.455	.000
		Group	-.791	.339	-.328	-2.333	.024
	2	(Constant)	4.551	.668		6.815	.000
		Group	-.802	.334	-.333	-2.405	.020
		P S Style	-.257	.162	-.220	-1.586	.120
	3	(Constant)	4.559	.716		6.364	.000
		Group	-.802	.338	-.333	-2.377	.022
		P S Style	-.254	.179	-.217	-1.418	.163
		Learning Style	-6.271	.179	-.005	-.035	.972

Broad Perception – Regression analysis: coefficients

Dependent Variables	Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
			B	*Std. Error*	*Beta*		
	4	(Constant)	4.851	.787		6.168	.000
		Group	-.730	.347	-.303	-2.102	.042
		P S Style	-.244	.180	-.208	-1.353	.183
		Learning Style	9.067	.180	.008	.050	.960
		L L Control	-.319	.351	-.132	-.908	.369
Total number of labels	1	(Constant)	22.722	3.307		6.870	.000
		Group	-7.337	2.162	-.451	-3.394	.001
	2	(Constant)	21.088	4.360		4.837	.000
		Group	-7.310	2.178	-.450	-3.356	.002
		P S Style	.614	1.057	.078	.581	.564
	3	(Constant)	21.185	4.677		4.530	.000
		Group	-7.308	2.204	-.450	-3.316	.002
		P S Style	.644	1.171	.082	.550	.585
		Learning Style	-7.254	1.168	-.009	-.062	.951
	4	(Constant)	26.828	4.727		5.676	.000
		Group	-5.913	2.088	-.364	-2.832	.007
		P S Style	.848	1.082	.108	.784	.437
		Learning Style	.224	1.082	.028	.207	.837
		L L Control	-6.160	2.108	-.379	-2.922	.006
Variety of labels	1	(Constant)	2.894	.294		9.845	.000
		Group	-.471	.192	-.343	-2.450	.018
	2	(Constant)	2.581	.382		6.756	.000
		Group	-.466	.191	-.339	-2.439	.019
		P S Style	.118	.093	.177	1.270	.211
	3	(Constant)	2.729	.404		6.752	.000
		Group	-.463	.190	-.337	-2.431	.019
		P S Style	.163	.101	.245	1.611	.114
		Learning Style	-.111	.101	-.167	-1.101	.277
	4	(Constant)	3.011	.435		6.918	.000
		Group	-.393	.192	-.287	-2.045	.047
		P S Style	.173	.100	.260	1.738	.089
		Learning Style	-9.631	.100	-.145	-.966	.339
		L L Control	-.308	.194	-.224	-1.585	.120
Flexibility of labels	1	(Constant)	2.637	.515		5.121	.000
		Group	-.676	.337	-.287	-2.007	.051
	2	(Constant)	2.681	.681		3.935	.000
		Group	-.677	.340	-.287	-1.987	.053
		P S Style	-1.650	.165	-.014	-.100	.921
	3	(Constant)	2.159	.691		3.125	.003
		Group	-.686	.325	-.291	-2.107	.041
		P S Style	-.176	.173	-.154	-1.019	.314
		Learning Style	.392	.173	.343	2.270	.028
	4	(Constant)	1.973	.763		2.587	.013
		Group	-.731	.337	-.310	-2.171	.036
		P S Style	-.183	.175	-.160	-1.047	.301
		Learning Style	.382	.175	.335	2.188	.034
		L L Control	.202	.340	.086	.594	.556

Divergency – Regression analysis: coefficients

Dependent Variables	*Model*		Unstandardized Coefficients *B*	*Std. Error*	Standardized Coefficients *Beta*	t	Sig.
Total Number of Ideas	1	(Constant)	10.810	2.639		4.096	.000
		Group	-3.310	1.725	-.275	-1.918	.061
	2	(Constant)	14.277	3.397		4.203	.000
		Group	-3.367	1.697	-.280	-1.984	.054
		P S Style	-1.304	.824	-.223	-1.583	.121
	3	(Constant)	11.275	3.375		3.340	.002
		Group	-3.420	1.590	-.284	-2.150	.037
		P S Style	-2.221	.845	-.380	-2.630	.012
		Learning Style	2.251	.843	.386	2.670	.011
	4	(Constant)	13.215	3.669		3.601	.001
		Group	-2.940	1.621	-.244	-1.814	.077
		P S Style	-2.151	.840	-.368	-2.561	.014
		Learning Style	2.353	.840	.404	2.800	.008
		L L Control	-2.118	1.637	-.176	-1.294	.203
Diversity of Ideas	1	(Constant)	3.788	.724		5.229	.000
		Group	-.941	.473	-.284	-1.988	.053
	2	(Constant)	4.187	.954		4.389	.000
		Group	-.948	.477	-.286	-1.989	.053
		P S Style	-.150	.231	-.093	-.648	.520
	3	(Constant)	3.587	.986		3.638	.001
		Group	-.959	.465	-.289	-2.063	.045
		P S Style	-.333	.247	-.207	-1.350	.184
		Learning Style	.449	.246	.280	1.825	.075
	4	(Constant)	3.500	1.093		3.203	.003
		Group	-.980	.483	-.296	-2.031	.049
		P S Style	-.336	.250	-.209	-1.345	.186
		Learning Style	.445	.250	.277	1.778	.083
		L L Control	9.492	.487	.029	.195	.846
Originality of Ideas	1	(Constant)	3.187	.644		4.947	.000
		Group	-.879	.421	-.297	-2.088	.042
	2	(Constant)	3.622	.846		4.280	.000
		Group	-.886	.423	-.300	-2.096	.042
		P S Style	-.164	.205	-.114	-.797	.430
	3	(Constant)	2.975	.858		3.466	.001
		Group	-.898	.404	-.303	-2.220	.032
		P S Style	-.361	.215	-.252	-1.682	.100
		Learning Style	.485	.214	.339	2.264	.029
	4	(Constant)	2.758	.948		2.910	.006
		Group	-.951	.419	-.322	-2.271	.028
		P S Style	-.369	.217	-.257	-1.701	.096
		Learning Style	.474	.217	.331	2.183	.035
		L L Control	.236	.423	.080	.559	.579

Convergency – Regression analysis: coefficients

Dependent Variables	*Model*		Unstandardized Coefficients *B*	*Std. Error*	Standardized Coefficients *Beta*	t	Sig.
Selection criteria	1	(Constant)	2.894	.691		4.185	.000
		Group	-.971	.452	-.305	-2.148	.037
	2	(Constant)	3.120	.913		3.416	.001
		Group	-.974	.456	-.306	-2.135	.038
		P S Style	-8.515	.222	-.055	-.384	.703
	3	(Constant)	2.184	.881		2.478	.017
		Group	-.991	.415	-.311	-2.386	.022
		P S Style	-.371	.221	-.240	-1.682	.100
		Learning Style	.702	.220	.455	3.187	.003

Convergency – Regression analysis: coefficients

Dependent Variables	Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
	4	(Constant)	2.686	.959		2.802	.008
		Group	-.867	.423	-.272	-2.047	.047
		P S Style	-.353	.219	-.228	-1.608	.115
		Learning Style	.728	.220	.472	3.317	.002
		L L Control	-.547	.428	-.172	-1.281	.207
Selection	1	(Constant)	3.476	.762		4.561	.000
		Group	-.976	.498	-.280	-1.960	.056
	2	(Constant)	3.168	1.006		3.149	.003
		Group	-.971	.503	-.279	-1.932	.060
		P S Style	.116	.244	.069	.475	.637
	3	(Constant)	2.378	1.017		2.339	.024
		Group	-.985	.479	-.283	-2.056	.046
		P S Style	-.125	.255	-.074	-.493	.625
		Learning Style	.592	.254	.351	2.331	.025
	4	(Constant)	1.891	1.112		1.700	.096
		Group	-1.105	.491	-.317	-2.250	.030
		P S Style	-.143	.255	-.085	-.562	.577
		Learning Style	.567	.255	.336	2.224	.032
		L L Control	.531	.496	.153	1.071	.290

Planning – Regression analysis: coefficients

Dependent Variables	Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
Mapping positive factors	1	(Constant)	1.996	.503		3.970	.000
		Group	-.689	.329	-.298	-2.095	.042
	2	(Constant)	2.663	.647		4.116	.000
		Group	-.700	.323	-.303	-2.164	.036
		P S Style	-.251	.157	-.223	-1.597	.117
	3	(Constant)	2.983	.678		4.397	.000
		Group	-.694	.320	-.300	-2.171	.035
		P S Style	-.153	.170	-.136	-.899	.374
		Learning Style	-.240	.169	-.215	-1.418	.164
	4	(Constant)	2.904	.752		3.864	.000
		Group	-.714	.332	-.309	-2.150	.037
		P S Style	-.156	.172	-.139	-.904	.371
		Learning Style	-.244	.172	-.218	-1.420	.163
		L L Control	8.638	.335	.037	.258	.798
Mapping negative factors	1	(Constant)	2.385	.514		4.638	.000
		Group	-.692	.336	-.294	-2.060	.045
	2	(Constant)	2.874	.671		4.286	.000
		Group	-.700	.335	-.297	-2.090	.042
		P S Style	-.184	.163	-.161	-1.132	.264
	3	(Constant)	2.662	.713		3.734	.001
		Group	-.704	.336	-.299	-2.096	.042
		P S Style	-.249	.178	-.218	-1.396	.170
		Learning Style	.159	.178	.140	.895	.376
	4	(Constant)	2.752	.790		3.486	.001
		Group	-.682	.349	-.289	-1.955	.057
		P S Style	-.246	.181	-.215	-1.360	.181
		Learning Style	.164	.181	.144	.908	.369

Planning – Regression analysis: coefficients

Dependent Variables	Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
		L L Control	-9.895	.352	-.042	-.281	.780
Listing preventive actions	1	(Constant)	1.755	.453		3.871	.000
		Group	-.639	.296	-.306	-2.157	.036
	2	(Constant)	2.216	.590		3.757	.001
		Group	-.647	.295	-.310	-2.194	.034
		P S Style	-.174	.143	-.171	-1.214	.231
	3	(Constant)	1.863	.612		3.044	.004
		Group	-.653	.288	-.313	-2.265	.029
		P S Style	-.282	.153	-.278	-1.838	.073
		Learning Style	.265	.153	.262	1.731	.091
	4	(Constant)	1.933	.678		2.852	.007
		Group	-.636	.299	-.304	-2.123	.040
		P S Style	-.279	.155	-.275	-1.798	.079
		Learning Style	.268	.155	.265	1.729	.091
		L L Control	-7.659	.302	-.037	-.253	.801
Planning steps	1	(Constant)	2.711	.662		4.095	.000
		Group	-.903	.433	-.297	-2.087	.043
	2	(Constant)	2.591	.875		2.960	.005
		Group	-.901	.437	-.296	-2.060	.045
		P S Style	4.503	.212	.031	.212	.833
	3	(Constant)	2.589	.939		2.756	.009
		Group	-.901	.442	-.296	-2.036	.048
		P S Style	4.436	.235	.030	.189	.851
		Learning Style	1.646	.235	.001	.007	.994
	4	(Constant)	2.270	1.034		2.195	.034
		Group	-.980	.457	-.322	-2.145	.038
		P S Style	3.281	.237	.022	.139	.890
		Learning Style	-1.509	.237	-.010	-.064	.949
		L L Control	.348	.461	.114	.754	.455
Comprehensiveness	1	(Constant)	2.258	.450		5.018	.000
		Group	-.701	.294	-.335	-2.382	.022
	2	(Constant)	2.647	.589		4.498	.000
		Group	-.707	.294	-.338	-2.404	.020
		P S Style	-.146	.143	-.144	-1.025	.311
	3	(Constant)	2.628	.631		4.163	.000
		Group	-.707	.297	-.338	-2.378	.022
		P S Style	-.152	.158	-.150	-.962	.341
		Learning Style	1.425	.158	.014	.090	.928
	4	(Constant)	2.539	.699		3.632	.001
		Group	-.729	.309	-.348	-2.362	.023
		P S Style	-.155	.160	-.153	-.970	.338
		Learning Style	9.579	.160	.009	.060	.953
		L L Control	9.705	.312	.046	.311	.757

Reflective Questionnaire

Sub-scale: Method – Regression analysis: coefficients

Dependent Variables	Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
Eliciting	1	(Constant)	45.993	3.571		12.880	.000
		Group	-4.377	2.334	-.269	-1.875	.067
	2	(Constant)	43.603	4.692		9.293	.000
		Group	-4.338	2.344	-.267	-1.850	.071
		P S Style	.899	1.138	.114	.790	.434

Sub-scale: Method – Regression analysis: coefficients

Dependent Variables	Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
			B	*Std. Error*	*Beta*		
Creating	1	(Constant)	27.150	2.649		10.250	.000
		Group	-3.766	1.731	-.308	-2.175	.035
	2	(Constant)	25.347	3.480		7.285	.000
		Group	-3.736	1.739	-.306	-2.149	.037
		P S Style	.678	.844	.114	.803	.426
Reflecting	1	(Constant)	29.740	2.677		11.111	.000
		Group	-4.894	1.750	-.385	-2.797	.008
	2	(Constant)	29.253	3.540		8.263	.000
		Group	-4.886	1.769	-.384	-2.762	.008
		P S Style	.183	.859	.030	.213	.832
Represen ting	1	(Constant)	17.205	1.070		16.078	.000
		Group	-1.936	.699	-.381	-2.768	.008
	2	(Constant)	17.815	1.409		12.645	.000
		Group	-1.946	.704	-.383	-2.764	.008
		P S Style	-.229	.342	-.093	-.671	.505
Support Method	1	(Constant)	25.147	2.165		11.613	.000
		Group	-3.454	1.415	-.342	-2.440	.019
	2	(Constant)	24.550	2.862		8.578	.000
		Group	-3.444	1.430	-.341	-2.409	.020
		P S Style	.224	.694	.046	.323	.748
Support Graphical Editor	1	(Constant)	9.007	.757		11.900	.000
		Group	-.623	.495	-.184	-1.259	.215
	2	(Constant)	9.401	.997		9.426	.000
		Group	-.629	.498	-.186	-1.263	.213
		P S Style	-.148	.242	-.090	-.612	.544
	3	(Constant)	9.372	1.070		8.760	.000
		Group	-.630	.504	-.186	-1.249	.218
		P S Style	-.157	.268	-.096	-.585	.561
		Learning Style	2.144	.267	.013	.080	.936
	4	(Constant)	8.885	1.172		7.583	.000
		Group	-.750	.518	-.222	-1.449	.155
		P S Style	-.174	.268	-.106	-.650	.519
		Learning Style	-4.153	.268	-.003	-.015	.988
		L L Control	.532	.523	.157	1.017	.315

Sub-scale: Learning Environment – Regression analysis: coefficients

Dependent Variables	Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
			B	*Std. Error*	*Beta*		
Explanation	1	(Constant)	4.220	.514		8.208	.000
		Group	-.681	.336	-.289	-2.027	.049
	2	(Constant)	3.811	.647		5.892	.000
		Group	-.682	.336	-.290	-2.032	.048
		Learning Style	.169	.163	.148	1.039	.305
	3	(Constant)	3.511	.732		4.799	.000
		Group	-.752	.346	-.319	-2.176	.035
		Learning Style	.150	.164	.131	.912	.367
		L L Control	.309	.348	.131	.888	.380
Examples	1	(Constant)	4.000	.426		9.394	.000
		Group	-.500	.278	-.259	-1.796	.079
	2	(Constant)	3.438	.524		6.560	.000
		Group	-.501	.272	-.259	-1.843	.072
		Learning Style	.232	.132	.248	1.763	.085
	3	(Constant)	3.367	.598		5.634	.000
		Group	-.518	.282	-.268	-1.834	.074
		Learning Style	.228	.134	.243	1.696	.097

Sub-scale: Learning Environment – Regression analysis: coefficients

Dependent Variables	*Model*		Unstandardized Coefficients *B*	*Std. Error*	Standardized Coefficients *Beta*	t	Sig.
		L L Control	7.301	.285	.038	.256	.799
Procedures	1	(Constant)	4.608	.490		9.402	.000
		Group	-.685	.320	-.304	-2.138	.038
	2	(Constant)	4.720	.624		7.569	.000
		Group	-.685	.324	-.304	-2.116	.040
		Learning Style	-4.641	.157	-.042	-.296	.769
	3	(Constant)	4.274	.696		6.138	.000
		Group	-.788	.329	-.349	-2.396	.021
		Learning Style	-7.470	.157	-.068	-.477	.636
		L L Control	.459	.332	.204	1.384	.173
Practice	1	(Constant)	4.143	.426		9.721	.000
		Group	-.143	.279	-.076	-.513	.611
	2	(Constant)	3.689	.531		6.947	.000
		Group	-.144	.276	-.077	-.522	.604
		Learning Style	.188	.134	.207	1.405	.167
	3	(Constant)	3.228	.587		5.502	.000
		Group	-.251	.277	-.134	-.904	.371
		Learning Style	.158	.132	.174	1.201	.236
		L L Control	.474	.279	.253	1.698	.097
Individual Approach	1	(Constant)	9.209	.864		10.658	.000
		Group	-1.747	.565	-.419	-3.094	.003
	2	(Constant)	9.087	1.100		8.260	.000
		Group	-1.748	.571	-.419	-3.061	.004
		Learning Style	5.041	.277	.025	.182	.856
	3	(Constant)	8.628	1.246		6.923	.000
		Group	-1.854	.589	-.444	-3.149	.003
		Learning Style	2.129	.280	.011	.076	.940
		L L Control	.472	.594	.113	.796	.430
Learnability	1	(Constant)	7.982	.863		9.251	.000
		Group	-1.443	.564	-.356	-2.559	.014
	2	(Constant)	8.020	1.099		7.298	.000
		Group	-1.443	.570	-.356	-2.530	.015
		Learning Style	-1.577	.276	-.008	-.057	.955
	3	(Constant)	7.925	1.254		6.322	.000
		Group	-1.465	.592	-.362	-2.474	.017
		Learning Style	-2.179	.282	-.011	-.077	.939
		L L Control	9.770	.597	.024	.164	.871
Explicit Support for the Method	1	(Constant)	4.941	.654		7.551	.000
		Group	-1.018	.428	-.334	-2.381	.022
	2	(Constant)	4.614	.830		5.562	.000
		Group	-1.019	.431	-.335	-2.367	.022
		Learning Style	.135	.209	.092	.649	.519
	3	(Constant)	4.666	.947		4.929	.000
		Group	-1.007	.447	-.331	-2.252	.029
		Learning Style	.139	.213	.094	.652	.518
		L L Control	-5.331	.451	-.018	-.118	.906
Explicit support for the Graphical Editor	1	(Constant)	4.088	.349		11.709	.000
		Group	2.747	.228	.018	.120	.905
	2	(Constant)	4.164	.444		9.372	.000
		Group	2.765	.231	.018	.120	.905
		Learning Style	-3.142	.112	-.042	-.281	.780
	3	(Constant)	4.133	.507		8.154	.000
		Group	2.053	.239	.013	.086	.932
		Learning Style	-3.337	.114	-.045	-.293	.771
		L L Control	3.165	.241	.021	.131	.896

Sub-scale: Interface – Regression analysis: coefficients

Dependent Variables	Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
			B	*Std. Error*	*Beta*		
Attractiveness	1	(Constant)	4.121	.242		17.063	.000
		Group	.225	.158	.208	1.427	.160
	2	(Constant)	4.118	.308		13.389	.000
		Group	.225	.160	.208	1.411	.165
		Learning Style	9.992	.077	.002	.013	.990
	3	(Constant)	4.135	.343		12.064	.000
		Group	.225	.162	.208	1.392	.171
		Learning Style	5.100	.086	.010	.060	.953
		P S Style	-1.010	.086	-.019	-.118	.907
	4	(Constant)	4.132	.380		10.873	.000
		Group	.224	.168	.207	1.334	.189
		Learning Style	4.930	.087	.009	.057	.955
		P S Style	-1.022	.087	-.019	-.117	.907
		L L Control	3.542	.169	.003	.021	.983
Graphical Editor	1	(Constant)	3.758	.416		9.039	.000
		Group	4.945	.272	.027	.182	.856
	2	(Constant)	3.201	.511		6.262	.000
		Group	4.818	.265	.026	.182	.857
		Learning Style	.230	.129	.261	1.792	.080
	3	(Constant)	3.154	.570		5.537	.000
		Group	4.949	.268	.027	.184	.855
		Learning Style	.219	.142	.248	1.539	.131
		P S Style	2.8282	.143	.032	.198	.844
	4	(Constant)	2.924	.625		4.676	.000
		Group	-7.239	.276	-.004	-.026	.979
		Learning Style	.207	.143	.234	1.444	.156
		P S Style	1.996	.143	.023	.139	.890
		L L Control	.250	.279	.137	.898	.374
Affordance	1	(Constant)	2.766	.512		5.404	.000
		Group	-7.326	.334	-.033	-.219	.828
	2	(Constant)	3.068	.647		4.738	.000
		Group	-7.257	.336	-.032	-.216	.830
		Learning Style	-.125	.163	-.115	-.768	.447
	3	(Constant)	3.394	.712		4.767	.000
		Group	-8.155	.335	-.036	-.243	.809
		Learning Style	-4.614	.178	-.042	-.259	.796
		P S Style	-.194	.178	-.178	-1.091	.282
	4	(Constant)	3.055	.779		3.923	.000
		Group	-.165	.344	-.074	-.480	.634
		Learning Style	-6.393	.178	-.059	-.358	.722
		P S Style	-.207	.178	-.190	-1.159	.253
		L L Control	.369	.347	.165	1.064	.294
Navigation	1	(Constant)	10.201	1.137		8.972	.000
		Group	-.125	.743	-.025	-.168	.868
	2	(Constant)	9.978	1.447		6.894	.000
		Group	-.125	.751	-.025	-.166	.869
		Learning Style	9.259	.364	.038	.254	.800
	3	(Constant)	10.815	1.584		6.826	.000
		Group	-.148	.746	-.030	-.198	.844
		Learning Style	.295	.396	.122	.746	.460
		P S Style	-.499	.397	-.206	-1.258	.215
	4	(Constant)	9.348	1.667		5.609	.000
		Group	-.511	.736	-.102	-.694	.492
		Learning Style	.218	.382	.090	.571	.571
		P S Style	-.552	.382	-.228	-1.447	.155
		L L Control	1.601	.743	.321	2.153	.037

Appendix 27 Map production – correlation analysis

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10	11.	12.	13.	14.	15.	16.	17.	18.
1. Final solution	Pearson Correlatio	1.00	.358*	.636**	.191	.603**	.431**	.176	.598**	.612**	.778**	.753**	.309*	.632**	.320*	.232	.423**	.498**	.564*
	Sig. (2-tailed)	.	.014	.000	.198	.000	.002	.236	.000	.000	.000	.000	.035	.000	.028	.117	.003	.000	.000
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
2. B P Nodes-tota	Pearson Correlatio	.358*	1.00	.829**	.272	.594**	.599**	.290*	.091	.234	.181	.004	.081	.174	.241	.076	.296*	.284	.498*
	Sig. (2-tailed)	.014	.	.000	.064	.000	.000	.048	.544	.113	.224	.978	.590	.243	.103	.609	.044	.053	.000
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
3. B P Nodes-Fluency	Pearson Correlatio	.636**	.829**	1.00	.208	.589**	.786**	.545**	.339*	.560**	.520**	.419**	.194	.202	.378**	.068	.500**	.556**	.644*
	Sig. (2-tailed)	.000	.000	.	.162	.000	.000	.000	.020	.000	.000	.003	.192	.174	.009	.649	.000	.000	.000
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
4. B P Nodes-Variety	Pearson Correlatio	.191	.272	.208	1.00	.279	.172	.026	.195	.164	.199	.132	.240	.114	.032	.215	.075	.149	.226
	Sig. (2-tailed)	.198	.064	.162	.	.057	.247	.864	.189	.270	.179	.375	.105	.444	.831	.148	.617	.316	.126
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
5. B P Nodes-Flexibility	Pearson Correlatio	.603**	.594**	.589**	.279	1.00	.542**	.228	.403**	.286	.351*	.240	.240	.101	.201	.166	.322*	.226	.430*
	Sig. (2-tailed)	.000	.000	.000	.057	.	.000	.123	.005	.051	.016	.104	.105	.500	.175	.264	.028	.126	.003
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
6. B P Labels- tota	Pearson Correlatio	.431**	.599**	.786**	.172	.542**	1.00	.749**	.471**	.452**	.356*	.298*	.284	.149	.332*	.039	.413**	.129	.246
	Sig. (2-tailed)	.002	.000	.000	.247	.000	.	.000	.001	.001	.014	.042	.053	.319	.022	.792	.004	.388	.095
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
7. B P Labels-variety	Pearson Correlatio	.176	.290*	.545**	.026	.228	.749**	1.00	.383**	.259	.260	.251	.096	.012	.190	.142	.021	.267	.076
	Sig. (2-tailed)	.236	.048	.000	.864	.123	.000	.	.008	.078	.077	.088	.519	.939	.201	.342	.888	.069	.609
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
8. B P Labels-flexibility	Pearson Correlatio	.598**	.091	.339*	.195	.403**	.471**	.383**	1.00	.559**	.670**	.712**	.296*	.567**	.142	.079	.320*	.294*	.260
	Sig. (2-tailed)	.000	.544	.020	.189	.005	.001	.008	.	.000	.000	.000	.043	.000	.340	.596	.028	.045	.077
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
9. Diverg. Ideas-total	Pearson Correlatio	.612**	.234	.560**	.164	.286	.452**	.259	.559**	1.00	.755**	.842**	.428**	.503**	.471**	.176	.641**	.547**	.568*
	Sig. (2-tailed)	.000	.113	.000	.270	.051	.001	.078	.000	.	.000	.000	.003	.000	.001	.236	.000	.000	.000
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
10. Diverg. Ideas-diversity	Pearson Correlatio	.778**	.181	.520**	.199	.351*	.356*	.260	.670**	.755**	1.00	.867**	.287	.677**	.270	.092	.515**	.615**	.647*
	Sig. (2-tailed)	.000	.224	.000	.179	.016	.014	.077	.000	.000	.	.000	.050	.000	.066	.539	.000	.000	.000
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
11. Diverg. Ideas-originality	Pearson Correlatio	.753**	.004	.419**	.132	.240	.298*	.251	.712**	.842**	.867**	1.00	.365*	.813**	.403**	.136	.548**	.599**	.500*
	Sig. (2-tailed)	.000	.978	.003	.375	.104	.042	.088	.000	.000	.000	.	.012	.000	.005	.362	.000	.000	.000
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
12. Converg. Selection criteria	Pearson Correlatio	.309*	.081	.194	.240	.240	.284	.096	.296*	.428**	.287	.365*	1.00	.470**	.257	.123	.504**	.051	.237
	Sig. (2-tailed)	.035	.590	.192	.105	.105	.053	.519	.043	.003	.050	.012	.	.001	.081	.412	.000	.735	.108
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
13. Converg. Selection	Pearson Correlatio	.632**	.174	.202	.114	.101	.149	.012	.567**	.503**	.677**	.813**	.470**	1.00	.214	.129	.539**	.332*	.292*
	Sig. (2-tailed)	.000	.243	.174	.444	.500	.319	.939	.000	.000	.000	.000	.001	.	.149	.386	.000	.023	.046
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
14. Planing Positive factors	Pearson Correlatio	.320*	.241	.378**	.032	.201	.332*	.190	.142	.471**	.270	.403**	.257	.214	1.00	.126	.446**	.270	.356*
	Sig. (2-tailed)	.028	.103	.009	.831	.175	.022	.201	.340	.001	.066	.005	.081	.149	.	.397	.002	.067	.014
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
15. Planing Negative factors	Pearson Correlatio	.232	.076	.068	.215	.166	.039	.142	.079	.176	.092	.136	.123	.129	.126	1.00	.019	.039	.032
	Sig. (2-tailed)	.117	.609	.649	.148	.264	.792	.342	.596	.236	.539	.362	.412	.386	.397	.	.901	.793	.830
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
16. Planing Prevent. actions	Pearson Correlatio	.423**	.296*	.500**	.075	.322*	.413**	.021	.320*	.641**	.515**	.548**	.504**	.539**	.446**	.019	1.00	.383**	.619*
	Sig. (2-tailed)	.003	.044	.000	.617	.028	.004	.888	.028	.000	.000	.000	.000	.000	.002	.901	.	.008	.000
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
17. Planing Steps	Pearson Correlatio	.498**	.284	.556**	.149	.226	.129	.267	.294*	.547**	.615**	.599**	.051	.332*	.270	.039	.383**	1.00	.850*
	Sig. (2-tailed)	.000	.053	.000	.316	.126	.388	.069	.045	.000	.000	.000	.735	.023	.067	.793	.008	.	.000
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
18. Planing Comprehensiv.	Pearson Correlatio	.564**	.498**	.644**	.226	.430**	.246	.076	.260	.568**	.647**	.500**	.237	.292*	.356*	.032	.619**	.850**	1.00
	Sig. (2-tailed)	.000	.000	.000	.126	.003	.095	.609	.077	.000	.000	.000	.108	.046	.014	.830	.000	.000	.
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix 28 Reflective Questionnaire – correlation analysis

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
1. Methhod - Eliciting	Pearson Correlation	1.00	.517**	.410**	.212	.055	.321*	.135	.281	.003	.147	.330*	.300*	.270	.221	.073	.004	.032	.168
	Sig. (2-tailed)	.	.000	.004	.152	.712	.028	.364	.056	.986	.324	.024	.041	.066	.135	.628	.980	.831	.258
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
2. Method Creating	Pearson Correlation	.517**	1.00	.845**	.159	.670**	.018	.152	.055	.183	.229	.474**	.791**	.758**	.110	.093	.111	.071	.374**
	Sig. (2-tailed)	.000	.	.000	.285	.000	.906	.308	.713	.218	.121	.001	.000	.000	.464	.535	.459	.633	.010
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
3. Method Reflecting	Pearson Correlation	.410**	.845**	1.00	.127	.805**	.132	.093	.037	.111	.112	.719**	.729**	.877**	.075	.201	.298*	.119	.332*
	Sig. (2-tailed)	.004	.000	.	.394	.000	.378	.535	.808	.459	.453	.000	.000	.000	.615	.175	.042	.426	.023
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
4. Method Representing	Pearson Correlation	.212	.159	.127	1.00	.202	.171	.105	.064	.273	.074	.029	.251	.090	.239	.274	.044	.094	.070
	Sig. (2-tailed)	.152	.285	.394	.	.174	.251	.483	.671	.064	.620	.848	.088	.549	.106	.062	.767	.529	.640
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
5.Method Support-Method	Pearson Correlation	.055	.670**	.805**	.202	1.00	.021	.052	.110	.184	.134	.540**	.675**	.749**	.005	.023	.206	.021	.110
	Sig. (2-tailed)	.712	.000	.000	.174	.	.889	.729	.460	.216	.368	.000	.000	.000	.974	.880	.164	.887	.463
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
6. Method Support-Gr.Ed.	Pearson Correlation	.321*	.018	.132	.171	.021	1.00	.269	.061	.056	.118	.144	.123	.014	.173	.159	.333*	.258	.357*
	Sig. (2-tailed)	.028	.906	.378	.251	.889	.	.068	.684	.711	.429	.334	.410	.926	.246	.285	.022	.080	.014
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
7. LE - Explanation	Pearson Correlation	.135	.152	.093	.105	.052	.269	1.00	.434**	.117	.267	.048	.002	.122	.034	.065	.163	.159	.145
	Sig. (2-tailed)	.364	.308	.535	.483	.729	.068	.	.002	.434	.069	.748	.992	.415	.823	.666	.274	.287	.331
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
8. LE - Examples	Pearson Correlation	.281	.055	.037	.064	.110	.061	.434**	1.00	.335*	.376**	.087	.158	.043	.397**	.008	.019	.167	.167
	Sig. (2-tailed)	.056	.713	.808	.671	.460	.684	.002	.	.021	.009	.561	.288	.776	.006	.958	.898	.261	.261
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
9. LE - Procedures	Pearson Correlation	.003	.183	.111	.273	.184	.056	.117	.335*	1.00	.363*	.002	.350*	.131	.042	.175	.043	.100	.018
	Sig. (2-tailed)	.986	.218	.459	.064	.216	.711	.434	.021	.	.012	.988	.016	.381	.777	.240	.773	.504	.903
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
10. LE - Practice	Pearson Correlation	.147	.229	.112	.074	.134	.118	.267	.376**	.363*	1.00	.188	.072	.006	.108	.070	.063	.000	.083
	Sig. (2-tailed)	.324	.121	.453	.620	.368	.429	.069	.009	.012	.	.207	.632	.968	.468	.638	.673	.998	.577
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
11. LE - Individual Approach	Pearson Correlation	.330*	.474**	.719**	.029	.540**	.144	.048	.087	.002	.188	1.00	.364*	.651**	.203	.139	.050	.093	.297*
	Sig. (2-tailed)	.024	.001	.000	.848	.000	.334	.748	.561	.988	.207	.	.012	.000	.171	.351	.737	.535	.043
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
12. LE - Learnability	Pearson Correlation	.300*	.791**	.729**	.251	.675**	.123	.002	.158	.350*	.072	.364*	1.00	.715**	.203	.044	.223	.202	.059
	Sig. (2-tailed)	.041	.000	.000	.088	.000	.410	.992	.288	.016	.632	.012	.	.000	.171	.770	.132	.174	.693
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
13. LE - Support Method	Pearson Correlation	.270	.758**	.877**	.090	.749**	.014	.122	.043	.131	.006	.651**	.715**	1.00	.170	.109	.461**	.170	.343*
	Sig. (2-tailed)	.066	.000	.000	.549	.000	.926	.415	.776	.381	.968	.000	.000	.	.254	.466	.001	.253	.018
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
14. LE - Support Graph. Ed.	Pearson Correlation	.221	.110	.075	.239	.005	.173	.034	.397**	.042	.108	.203	.203	.170	1.00	.120	.371*	.051	.134
	Sig. (2-tailed)	.135	.464	.615	.106	.974	.246	.823	.006	.777	.468	.171	.171	.254	.	.420	.010	.733	.370
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
15. Interface - attractiveness	Pearson Correlation	.073	.093	.201	.274	.023	.159	.065	.008	.175	.070	.139	.044	.109	.120	1.00	.461**	.005	.041
	Sig. (2-tailed)	.628	.535	.175	.062	.880	.285	.666	.958	.240	.638	.351	.770	.466	.420	.	.001	.972	.786
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
16. Interface - Graph. Edditor	Pearson Correlation	.004	.111	.298*	.044	.206	.333*	.163	.019	.043	.063	.050	.223	.461**	.371*	.461**	1.00	.141	.125
	Sig. (2-tailed)	.980	.459	.042	.767	.164	.022	.274	.898	.773	.673	.737	.132	.001	.010	.001	.	.343	.404
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
17. Interface - Affordance	Pearson Correlation	.032	.071	.119	.094	.021	.258	.159	.167	.100	.000	.093	.202	.170	.051	.005	.141	1.00	.602**
	Sig. (2-tailed)	.831	.633	.426	.529	.887	.080	.287	.261	.504	.998	.535	.174	.253	.733	.972	.343	.	.000
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
18. Interface - Navigation	Pearson Correlation	.168	.374**	.332*	.070	.110	.357*	.145	.167	.018	.083	.297*	.059	.343*	.134	.041	.125	.602**	1.00
	Sig. (2-tailed)	.258	.010	.023	.640	.463	.014	.331	.261	.903	.577	.043	.693	.018	.370	.786	.404	.000	.
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).