The Art and Science of Problem Solving

René Victor Valqui Vidal †

† Informatics and Mathematical Modelling
Technical University of Denmark
2800 Lyngby
Denmark
vvv@imm.dtu.dk
www.imm.dtu.dk/∼vvv

Study the science of art
and the art of science.
- Leonardo da Vinci

Abstract

In this paper we will document that real-life problem solving in complex situations demands both rational (scientific) and intuitive (artistic) thinking. First, the concepts of art and science will be discussed; differences and similarities will be enhanced. Thereafter the concept of group problem solving facilitation both as science and art will be presented. A case study related to examination's planning will be discussed to illustrate the main concepts in practice. In addition, other cases studies will also be shortly presented.

Keywords: Problem solving, art, science, facilitation, group work

1 Introduction

In our educational institutions and in our culture in general, there is a split between art and science. It is believed that these two ways of working and thinking, the artistic attitude and the scientific attitude are two very different worlds, they are like oil and water. Although the link between art and science has historically been very close, exemplified by Leonardo da Vinci, the ideal that Leonardo represents is really not agreed upon by the art and science communities. It is the opinion of the author of this paper that this distinction between and separation of art and science is artificial and increasingly anachronistic. Fortunately things are changing; new fields arise from the synthesis of other fields. For instance, scientists are

relaying more and more on visual communication, and artists are working increasingly with computers. There is a common place to transfer information, ideas and knowledge. Visual problems are ultimately the same across disciplines. For example, Computer Graphics is a new field made up of art and science.

Another interesting field that demands knowledge and experience from art and science, as well as other disciplines, is Modern Design. The book of Nelson and Stolterman (2003) is a coherent meta-theoretical and holistic approach to a design theory applicable to any context. This book is valuable and useful: full of many conceptual and practical ideas; given an integrated picture of central theories and concepts about design. In addition, it brings together qualitative and creative issues from Art and Architecture with quantitative and scientific approaches of Operational Research and Engineering. The authors do this by founding their concepts and analyses on the epistemological foundations of Systems Thinking.

Another valuable contribution related to management and problem solving is the book edited by Boland and Collopy (2004). The main premise of this book is that: *managers should act not only as intelligence gatherers and decision makers, but also as creative designers.* Though decision and design are inextricably linked in management action, managers and scholars have too long emphasized the decision aspect of management over the design aspect. The main message of this book is that managing is not only decision making but also designing. This collection of papers explores the "design attitude" as opposite to the "decision attitude", that draws on examples of managing in architecture, art, and design. This volume is a critique of the predominant management education that focuses on training students to make choices among the alternatives presented to them, rather than training them to design new alternatives. In a series of brilliant and wide-ranging essays from a multitude of disciplines, the authors develop a theory of the design attitude that contrasts with the more traditionally accepted and practiced decision attitude. Their innovative view of management promises to provide a way into some of the most pressing issues facing organizational leaders, researchers and educators today. The editors have designed a thought-provoking volume that portrays management not as a science of rational problem solving but, instead as the art of generating visions and roads for achieving these visions. This collection of papers will inspire, enlight, intrigue, challenge, and teach readers about designing organisations.

In 1981, Ackoff (1981) published a paper entitled: *The art and science of mess management.* He argues that there are three kinds of thing that can done about problems:

- The *clinical approach*, where you select actions that are good enough, that *satisfices*; it relies heavily on past experience, it is qualitatively oriented, and it is rooted deeply in common sense making use of subjective judgements.
- The *research approach*, where you select actions that are the best possible outcome, which *optimizes*; it is largely based on scientific methods; it is quantitative oriented, and it makes use of mathematical models aspiring to complete objectivity. And
- *The design approach*, where you seek to change the nature, and the environment of the problem so as to remove the problem, it *dissolves* the problem; it idealizes rather than satisfice or optimize because its objective is to change the system involved or its environment in such a way as to bring it closer to an ultimately desired state, one in which the problem cannot or does not arise; it is innovative oriented and it makes use of creative and participative approaches aspiring dissolution in the containing whole.

The last approach is based on the two first approaches, practical experience and scientific approaches, but he adds design, invention, creativity, participation, and facilitation. This is the art and science of problem solving.

The main purpose of this paper is to reflect, elaborate and document about how the concept of "the art and science of problem solving" can be used in the real world to deal with important problematic situations in Society. Here, the facilitator is both the artist and scientist supporting a group to deal with a mess. As a scientist, he will be using when needed scientific approaches, experimentation, simulation and mathematical modelling in the problem solving process. As an artist, he will metaphorically speaking be like a painter who combines colours and shapes (the participants in the process) to create an art work (the problem solving process). Or, the facilitator is the director of a theatre performing a piece of art.

Art and Science are both historically and culturally laden concepts. Modern concepts of Art and Science will be discussed in Sec. 2 and 3, respectively. Sec. 4 will elaborate on the differences between Art and Science while Sec. 5 discusses their similarities. In Sec. 6 the different elements of the facilitation of problem solving will be presented as well as the art and science of problem solving. Our discussions of Sec. 6 will be more concrete by presenting a case study: the design of a decision support system for the planning of oral examinations in high schools in Denmark; this will be the subject of Sec. 7. In section 8 other case studies will be presented and finally in the last section, Section 9, the conclusions are depicted.

2 What is Art?

The answer to this question is conditioned by the fact that a definition of art has changed due to cultural and historical reasons. The boundaries of art have experienced a radical change over the last century. Previously, art was created in historically validated media and presented in a limited set of contexts for a limited set of objectives, such as search of beauty, religious glorification, or the depiction of persons and places. However, this century has produced new ways of experimentation, breaking and testing of boundaries. Artists have introduced new media, new contexts, new materials and new purposes. The art institutions have assimilated much of this experimentation, some of them depicted in the following list:

- Abstract painting (Pablo Picasso)
- Ready-mades (Marcel Duchamp)
- Interventions in non-art settings (Superflex)
- Performance art (Tracey Emin)
- Use of industrial materials, products and processes (Andy Warhol)
- Conceptual art (Joseph Beuys)
- Land art (Robert Smithson)
- Interactive art (Olafur Eliasson)
- Public art (Diego Rivera)

- Video art (Peter Land)

This expansion in art activities causes a difficulty in achieving consensus on definitions of art. The following very general definition can be easily accepted:

Making art may be depicted as the process of responding to perceptions, feelings, ideas, dreams, and other experiences by creating innovative works of art through the skillful, thoughtful, and imaginative application of tools and techniques to various media and materials. The "objects" of art that result of encounters between artists and their intentions, their interventions, their concepts and attitudes, their cultural and social realities, and the materials or media in which they choose to work.

Modern artists use unorthodox materials, tools, techniques and ideas inspired by the worlds of science, technology, humanities, economics, psychology, sociology, anthropology, etc. Some are present in non-art contexts, such as factories, laboratories, trade shows, the Internet, schools, and the street. Social interventions are manifold. The process of creating art is fill up of problems related to design and decision-making. The design attitude is related to the creative and innovative process in problem solving, while the decision attitude is related to the scientific approach to problem solving. In this sense, science can support art both providing materials and the media, and rational approaches to problem solving.

3 What is Science?

Researchers and philosophers on science suggest several defining elements. This set of core ideas, *the scientific approach*, includes the following:

- An essay to understand how and why phenomena occur
- Focus on the real (natural, social, human) world
- Focus on empirical information
- Seeking objectivity
- Use of a rational or logical approach
- Knowledge codify into laws and principles, and
- The continuous testing and refinement of hypotheses.

The crucial assumptions of the scientific approach are that the observed world is essentially orderly, and objectivity can be achieved through self-discipline and the reliance on methods such as the calibration of instruments, repeatability and multi-observed verification. There are of course variations in emphasis. That is, empiricists focus primarily on the role of observations, while rationalists emphasizes on the logical processes of theory construction and derivation. Some enhance induction built from observation; others focus on deduction drawn from theory.

Critical scientists see science as a modern delusion, challenging mainly the possibility of objectivity, noting the decisive influences of gender, social position, culture and history. Critical science is focusing in issues such as the interactions of the observer and the observed phenomena; the role of socially constructed frameworks at all stages; and the social forces and metanarratives that form the questions and paradigms used in the research process.

Several researchers have contributed to the critique of science. One describes the way dominant paradigms shape the questions that get acceptance and support. Another critiques assumptions of scientific rationality, remarking that nature gives different answers when approached differently. Others analyze the metaphoric language of science, its authoritative voice, and its unacknowledged patriarchal underlife.

In social sciences and the humanities, this kind of critique predominates. Scientists and technological innovators, however, believe in the ability to discover universal truths and assert that reform can overcome those places where scientific process falls short of its aspirations to universality and objectivity. As validity, it is usually referred to the accomplishments of the rational approach in building robust theoretical structures, and in predicting and controlling the material, organic and social world.

4 Art vs. Science: Differences

Box 1 depicts the main differences between art making and science making. Einstein (1934) has stated that the artist and the scientist each substitute a self-created world for the experiential one, with the purpose of transcendence. The main difference is that the artist is guided by an "artistic attitude" while the scientist is guided by a "scientific attitude". These attitudes are characterized in Box 1.

Artists are reflective and intuitive persons; materializing and visualising subjective experiences; and breaking the boundaries and traditions. Scientists are logical and rational persons; formulating verbally objective theories and principles; and seeking to improve and optimize. Scientists in their work are usually problem solvers, which are selecting course of actions that is believed to yield the best possible outcome. Artists are usually problem dissolvers, which are changing the nature and the environment of the system where the problem is imbedded so as to remove the problem. These differences are not exclusive; this means that sometimes the artists will be working as scientists and vice versa, during their working process and problem solving process.

5 Art vs. Science: Similarities

Box 2 describes the main similarities between art and science. Both value the careful observation of their environment to gather information through their senses. Creativity and innovation play a central role in both activities. To introduce change or improvement over the existing is of great concern to artists and scientists. Artists as well as scientists work with abstract symbols, representations for various realities and working tools. Even the language used by the two groups can be similar. Scientists working with mathematical models sometimes describe a particular good explanation or result as elegant or beautiful. The intellectual

Differences:

Art	Science
• Aesthetic, reflective	• Know, understand
• Emotion, intuition	• Reason, logic
• Idiosyncratic, personal	• Normative, principles
• Visual, sonic	• Narrative, textual
• Evocative, subjective	• Explanatory, objective
• Radical change	• Improve, optimise

Box 1: Art vs. Science: Differences

bridge of abstraction and aesthetic consideration is fundamental for both groups. Finally, both aspire to create works that have universal relevance.

These similarities provide many interest fields where art and science can support each other in their working processes. One of them is the interaction between creative and rational processes in real life problem solving. Another is artists being the facilitators of problem solving processes in scientific approaches. Modern artist are also inspired by new developments in science and technology, for instance the exhibitions of Olafur Eliasson (2004). Modern management scientists and researchers of problem solving approaches are also moving from the classical scientific approach towards a more artistic and design oriented attitude that is needed when innovation is needed in an organisation. In a modern world everything can become art, and everything can be studied scientifically.

Art vs. Science: similarities

- Observation, experimentation, sensual
- Creativity
- Change, innovation, improvement
- Models, symbols, abstraction
- Universality

Box 2: Art vs. Science: Similarities

6 The Facilitation Process

Let us see now the different elements of the facilitation process when applied to problem solving of real-life problems.

6.1 The Scene

The point of departure in our discussions is the concept of an *organization.* An organization can be a family, a community, a corporation, or an institution. What characterizes organizations is that they are purposefully designed and specialized to achieve a task. Thus an organization in a community could be a centre designed to enforce the development of the region, while firms are organizations providing some products and profits, and institutions are organizations designed to provide some services. The evolution of organizations is conditioned by external and internal factors, and sometimes organizations are experiencing *problematic situations or messes,* that are complex situations where some purposeful action is demanded to achieve some goals and visions. Problematic situations are usually related to the introduction of new technology, the re-design of the organization, the development of new strategies for the organization, the formulation of new visions for the future, or problem solving in general. In such a situation, the organization will usually appoint *a work group* to deal with the problematic situation. The *task* of this group is to analyze the mess and answer the question: What is to be done? In other words, to propose *actions plan* to be approved by the *decision-makers* of the organization. In small organizations the decision-makers (managers) are usually part of or identical to the work group. Related to these persons we have the so-called *stakeholders*, those individuals outside or inside the organization that can either affect or be affected by the actions plan. Let us see two examples to clarify the above-mentioned concepts.

Example 1: A small firm

The organization in question is a small firm in a retail business. The problematic situation is to what extent to engage in e-businesses as demanded by the bigger partners in the supply chain and what will eventually be the configuration of the technological platform to be used. The situation is also problematic because the organization has neither the technological background to identify different technological alternatives nor the experience for dealing with problematic situations. Management (the decision- makers) has appointed a work group (one person) to deal with this mess. The stakeholders are: the shareholders, the suppliers and the different type of purchasers.

Example 2: Community Work

The organization in question is a Development Centre in Odsherred (DCO), a vulnerable local region of Denmark. This is an autonomous non-profit organization which main objectives are to strengthen, develop, and inspire all type of cultural, social, environmental, and commercial activities in the region. Local innovators, in close co-operation with the relevant stakeholders of the region, carry out projects. These projects as well as the DCO itself are financed through a mix of sources: public funds, private funds, sponsors, business activities, and LEADER+, an EU-program that supports development in vulnerable regions of the countries that are members of the EU.

The problematic situation is the development of common images of ideas, projects, visions, and objectives for the region in question. These visions and objectives will be used to select the projects to be supported by the LEADER+ program. The DCO's board (the decision-makers) appointed a work group to deal with this situation. The stakeholders are: NGO's from the region, the business community, trade unions, local innovators and officials from the different municipalities.

To deal with messes, it is recommendable for the work group to hire *a facilitator*. A facilitator will support the group in the *problem solving process*; he or she will secure that the problem solving process ends with an action plan. The facilitator is usually the manager of the problem solving process. The facilitator could also give some expert know-how or find out if some experts have to be hired to give specialized advice. Often, the facilitators as professionals have some technical expertise for instance within information technology, so that he or she could also be the expert. To perform his job as process manager, the facilitator uses some *approaches, methods and tools* that he finds suitable for the given situation. The approaches could be quantitative (hard), qualitative (soft), participative (critical), innovative (creative) or a combination of them (multi-methodology). To facilitate groups demand the ability to both design and manage problem solving processes, creating a pro-active atmosphere and synergetic effects. Fig. 1 summarizes all the elements and concepts discussed above that will be further elaborated in the rest of this paper.

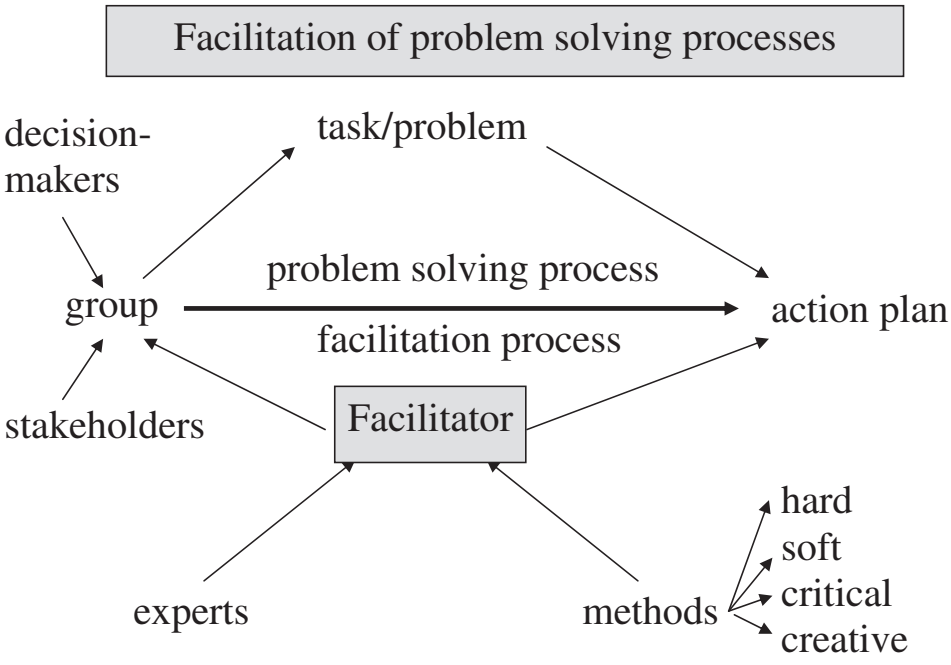

Figure 1: The facilitation process

Example 1 (continued)

In the above-mentioned example the facilitator was a student working in his MSc thesis to obtain a degree in Computer Engineering and Operational Research. The facilitator was also the technical expert. The problem solving process had a duration of around 3 months. The facilitator used several soft approaches during the problem solving process. The final product was an action plan elaborating the different realistic alternatives and a proposal for the decision-makers. The whole case study has been reported in Sørensen, Vidal, and Engström (2004).

Example 2 (continued)

The director of DCO contacted the author of this paper to support the organization and facilitation of a one-day Vision Conference. The purposes of this conference were both:

1. To generate visions and projects that would create a sustainable development of the region, and
2. To learn how to facilitate work groups, a tool that will be used during the implementation process of the LEADER+ program.

The facilitator designed and managed the Vision Conference where several creative techniques were used. The final result was a long list of potential projects. This will be used in the debates of the DCO's board while allocating funds to some selected projects. This case study has been reported in Vidal (2004a).

6.2 Social Interventions

In the two examples mentioned above, we have in principle two different kinds of social interventions. In the first one, denominated **research-driven intervention**, it is the facilitator as a researcher that takes the initiative to find a real-life case study for his MSc thesis. His objective is to test a problem solving approach and to evaluate the applicability of some methods. Obviously, the client or user will benefit by learning about the problematic situation, but there are not doubts about whose needs are ultimately driving the inquiry and helping process. This kind of intervention is quite similar to the type of interventions carried out under the name Action Research (Whyte, 1996). When Action Research was first formulated, it was clearly a case of the researchers wanting to figure out how to be more successful in implementing some changes that the researchers desired. It was found that by involving the targeted population in the research process, they became more amenable and committed to the desired change. But the initial drive came from the change agent and it was the change agent's goals that were driving the intervention. This research practice involves the client system in the researcher's agenda even though the client system might ultimately be the beneficiary. But the client did not initiate the process and it was not the client's needs that drove the process. It was the researcher's choice to involve the client.

The second example illustrates what is known as a **user-driven intervention**. The work group was composed of professionals covering different disciplines and with a lot of experience in problem solving within their own fields. In this case study, it is the client's needs that

are driving the inquiry and supporting process. During the problem solving process the work group will need support from experts, as for example the organization of a conference and the teaching of facilitation tools. In this mode of intervention, learning is a very important aspect of the problem solving process, because next time the users will organize a conference without an external facilitator and facilitation will become a tool in their future work. This form of intervention is usually found in the praxis of many consulting disciplines as for instance Management Sciences, Systems Sciences and Operational Research.

A third mode of intervention is denominated **participative intervention**, where both the work group and the facilitators co-operate and collaborate from the very beginning in the design of a problem solving process to deal with the problematic situation. This form of intervention is usually necessary when there is a need of both the practical experiences of the work group and the methodological and other expert knowledge from the facilitators. This mode of intervention can be regarded as a synthesis of the other two modes described previously.

Example 3: Public planning

It is my experience that my students start a social intervention as a research-driven form to be used as a case study for their MSc thesis work. Later, some of these studies evolve to a participative intervention seeking to develop and to implement the results achieved in the first intervention. This is for instance the case study reported in Hansen and Vidal (1995), the implementation of a computerized decision support system at The Ministry of Education in Denmark to plan the annual oral examinations at all the high schools of the country. This is a large-scale logistic and scheduling problem. The problem was solved using a whole system of hard methods developed by computer engineers under the facilitation of a systems analyst in close cooperation with a group of planners from the ministry. Since 1992, this system has been used in real-life planning. This case study will be further discussed in Sec. 7.

6.3 The Art and Science of Facilitation

The success of the problem solving process is determined by the effectiveness and creativity of the work group. Since the participants are invited or appointed, it is recommended to use some selection criteria. Some of these criteria could be: Representability, goal compatibility, process compatibility, deliberation abilities, positivism, communication abilities, and focus abilities. Obviously, the quality of performance or the piece of art created depends of the raw material you are using.

It is clear that selecting the participants is a very important task, which has to be solved seriously in order to develop effective group work and high quality results. A person, with knowledge and experience with working collaboratively with people, from the organisations involved should undertake this task.

In connection with the group work, there are two social processes to be managed by the facilitator: the problem solving process and the group process. The problem solving process is the way the group acts to solve the task supported by the facilitators and some experts. This is the rational and logical process. The group process is related to the manner in which the individuals in the group work together, how they learn, how they communicate, their social and power relationships, and how they deal with conflicts. This is the intuitive and creative

process. Obviously, these two processes interact in various degrees. In ideal group work, these two processes support each other. We talk about **group dynamics**, when energy and synergetic effects are created in the group work as a result of well-balanced processes where the task is just as important as the group trust and identity.

In addition, there is a third social process: the facilitation process. The facilitators are the managers of the social process and their main mission is to inspire, create, direct, and support group dynamics. By focusing and guiding group members' communication and decision-making processes in a creative and structured form, the facilitators can reduce the chances of engaging in faulty processes and harness the strengths of the group. The facilitator is both an artist, being the director of an artistic performance to be performed by the group, and a scientist, supporting a scientific approach to problem solving. This situation can be achieved using the following guidelines:

- Use approaches, for example creative techniques, and scientific methods;
- Specify a set of objective ground rules for the group work;
- Build on the strengths of the group and protect the group against its weakness;
- Balance members participation;
- Support the group with technological know-how;
- Support the group while dealing with conflicts;
- Plan time to close the different social processes;
- Make the group reflect and evaluate the group dynamics; and
- Empower the group.

The facilitators are constantly thinking (reflection) and listening to the deliberations in the group so they can make suitable interventions (decision making). An intervention means communicating with the group, giving information and knowledge, and encouraging the participants to think about important topics.

Let us elaborate now more theoretically about the essence of the facilitation process as opposed to its existence or its accidental qualities or, in other words, the attributes by means of which facilitation as management can be qualified or identified. As we have seen, facilitation is a purposeful process carried out by one or several persons that goes forward between two interacting processes. First, the logical/rational/legal process carried out by a purposeful group (the problem solving group) that wants to achieve some goals. This process has been called the problem solving process, and is the scene of objectivity. Secondly, the non-logical/irrational/illegal process that refers to the chaotic social process provoked by each single participant, by the participants' relations to each other, or by the participants' relations to the facilitator of the purposeful group, these bring into the participants own subjectivity, intuition, fantasy and feelings. This process can be called the problem destruction process and is the scene of subjectivity.

The facilitation process will move in the grey zone between the scene of objectivity and the scene of subjectivity. The rational and the irrational processes are fighting one another;

the one wants to impose over the other. They are in conflict with each other, but they need each other because while the problem solving process seeks to achieve realistic solutions, the irrational process will be the basis for the production of new ideas. Rationality needs chaos, and chaos needs rationality. Due to this contradiction, rationality vs. chaos, we can stipulate that facilitation is a **dialectical** process.

Let us also emphasise that facilitation is a purposeful intervention in a social process, a designed process. Facilitation is not a necessity for the evolution of the problem solving process but it is designed to support the problem solving process. The facilitation evolves very dynamically in a grey zone trying to construct a bridge between the traditional/conservative problem solving (business as usual) and the new/revolutionary power to change. The purpose of facilitation is to seek that the two above-mentioned processes do not destroy each other, but on the contrary support each other.

The facilitation process can be instructed and directed in different manners, as there are several management styles. The facilitators are the managers of this process. Note that if the group can manage itself, there is no need for a facilitator. That is, the group can learn to facilitate itself. As in any management process, it is a good idea to develop a strategy and design an action plan for the facilitation process. Managing by designing is a fundamental principle in any facilitation process (Boland and Collopy , 2004), therefore all the social processes have to be designed.

Management also involves three other central factors: Power, communication and learning. These aspects are always present in any facilitation process and should be reflected and articulated before, during and after the process. Facilitation becomes **an art** when a synergistic effect is achieved due to the constructive interaction between the rational and the irrational processes. The facilitator then becomes the director of a performance, where each participant plays a central role. By the end of the performance if synergy has been created all the participants will explode in a rush of happiness and pleasure, the pleasure of working creatively and collectively to achieve some goals. It is the same feeling that football players experience after a match where the victory has been the result of a combination of individual creativity, collective hard work and suitable facilitation (the coaching).

Summarising, we can state that the purpose of facilitation as management is not only to solve the task, but other additional goals could be:

- Each participant is a potential facilitator, therefore the importance of the learning dimension;

- Empowerment, the participants learn to be more self-confident and learn to work creatively in a group (creativity is an act of liberation from the jail of our own routines!); and

- Praxis, the facilitators should be able to learn from the experience therefore the importance of the evaluation of the intervention and the systematisation of praxis (Vidal, 2004b), in addition learning from failure is a good principle for any facilitator.

7 Case Study: Planning of High School Examinations in Denmark

In this section, the case study presented as Example 3 in Sec. 6.2 will be further discussed. This is a real-life logistic problem where a computer based support system has been developed and implemented. The system has been running at the Danish Ministry of Education since 1992.

7.1 Background

In Denmark, all planning of the official examinations at high school level is centralized at the Danish Ministry of Education. Denmark is the only country where such planning activities are centralised nationally. This cumbersome task had become increasingly difficult and time consuming due to educational reforms in 1998. In 1990, it was decided at the Ministry to develop a computer based decision support system to aid the ministerial planners in this planning process.

The Danish academic school system is divided into primary school (grade 1 through 9/10), high school (grade 10/11 through 12) and university/college, where primary school is the only compulsory school. High school, in the broad sense, has several channels, the academics as opposed to the technical or commercial high schools being the most attended ones. Approximately one half of all primary school graduates continue onto an academic high school.

The academic high school system has two major channels: The Gymnasium which is a 2 or 3 years package, 3 years being the most common, and higher preparatory school (HF), a two years package Through a system of merits, it is also possible to obtain an equivalent qualification through individual study-plans over several years (VUC). Denmark has 77 Gymnasiums, 25 HF-schools, 77 VUC-schools and 69 schools with both Gymnasium and HF curricula. This amounts to approximately 115,000 students and 12,000 teachers.

The students of the Gymnasium and HF are evaluated at the end of each school year. This evaluation includes oral and written examinations in certain courses. The planning of written examinations is much simpler since the days of examination are given before the start of the school year. This is necessary since all students answer the same examination questions and obviously they must do this at the same time. In what follows *examination* means oral examination. A *censor* is an eligible and ministerial appointed person - usually a high school teacher from another school – and an *examiner* is the person who conducts the examination – usually the teacher of the course.

An examination is carried out in the following way: A censor arrives at the school to observe the examination of each student conducted by the examiner for a fixed amount of time. After each student examination, the censor and the examiner agree on a grade for the student and then continue with the next student on the course, if any.

To encourage students to exhibit "good student behaviour", i.e. not miss classes, deliver term papers on time, etc., a bonus is granted in terms of a reduced number of examinations. Almost 95 percent of all students achieve this bonus. While a final year student could be examined in 7 subjects, "good students" will only have to attend 3 or 4 examinations. The

decision of which 3 or 4 subjects the student is to be examined in is drawn in private for each student and is not revealed until the last school day. Consequently, the student must prepare himself for all 7 subjects during the regular school year.

The examinations are gathered in a reserved 5 week period at the end of the school year from mid May to mid June. The Gymnasium only uses the last 3 weeks, except for final year students who also use the second week. First year HF-students use the last 4 weeks and VU-students and final year HF-students use all 5 weeks. Except for national holidays (which have a maximum of three whole days), the examination are placed Monday-Friday.

Previously, the examination planning was carried out by examination planners at the Ministry of Education using pencil and, especially eraser. Data was reported from each school on paper and sent by snail mail. In 1990, it was decided at the Ministry to develop an information system containing all relevant school data. The basic system is now an Oracle database with applications developed using Oracle tools and C-programming. Different systems are attached to the database, the examination system being the largest and most complex. A communication system handles the input of new data which is submitted from the schools to the ministry on floppy disks.

7.2 The problem and the approach

Summarizing, we can state that the task is to design and implement a computer based decision support system to plan and schedule the annual oral examinations for secondary education in the whole Denmark. For each student, it has to be decided:

- The number of oral examinations
- The subjects to be examined on
- The day, hour and room number for the examination
- The examinator, and
- The censor.

In practice, there are two main interrelated factors that determine the process of the solution of the above mentioned problem. The *technical approach*, i.e. the suitability of the techniques, methods, software, procedures, and so on, included in the whole decision support system, and the suitability of the *social process* related to the problem solving process itself. In Hansen and Vidal (1995), the technical approach has been described. The second factor demands close interaction and collaboration between the group work, decision makers, experts, consultants and facilitators. In this paper, we will primarily be focusing on the social processes though some aspect of the first factor will be shortly mentioned.

The planning problem described above is a complex and quite difficult combinatorial problem. It contains many decision variables; it has a variety of objectives and many feasible and satisfying solutions. We shall now elaborate on these observations.

Real life planning situations are usually complex. The examination planner has to comply with national laws and habits and must assist schools with their specific problems, making the

examination period as smooth as possible. Obviously, a computer system should support him in this task, rather than introduce additional limitations.

The examination timetabling problem is well known for its mathematical difficulty (Eiselt and Laporte, 1987). This is also true for the assignment problems related to our planning problem. Since a student will normally take more than one examination, a school may have as many as 1500 student examinations. Each student examination is to be scheduled on a specific day, which produces very many decision variables. This assignment problem will contain more than 100 million binary decision variables if formulated as a traditional 0-1 optimization problem.

Having multiple objectives is an ingrained feature of real life problems. These criteria involve a good spread of student examinations so as to provide good premises for each student, minimising the costs for the schools, the counties, and the Ministry, and sharing pedagogical benefits equally among the schools, subjects and geographical areas.

After experimenting with prototypes containing preliminary algorithms, it was concluded that finding feasible solutions did not present major difficulties. Finding satisfying solutions was more difficult but was still consider being attainable within reasonable amount of algorithm construction, system implementation effort and computational time. No demands for achieving optimal solutions were given whereas robustness and consistency were considered to be more important. This is in line with the following heuristic principle: Managerial decisions might be improved more by making them more consistent from one time to another than by approaches seeking optimality to explicit cost models; especially for situations where intangibles must otherwise be estimated or assumed.

These observations led to the conclusion that the final planning system should provide the examination planner with suitable information and optimising tools based in heuristic methods, which could be used interactively and that could be stopped at the users command yielding satisfying solutions.

To cope with the complexity of the problem at hand, it will be decomposed into four interrelated phases, each dealing with separate tasks and having well-defined goals following well-known heuristic principles (Silver et al, 1980). This decomposition approach follows to a certain extent the traditional approach (pencil and eraser) at the Ministry; this makes easier the final implementation process. This traditional approach was very time consuming for two planners with a lot of helpers. These four phases are:

- Subject draft
- Examination Chain
- Examination Scheduling
- Assignment of Censorships.

7.3 The work group and the stakeholders

The decision maker was the chief of the Examination Department at the Ministry. He is responsible that all the processes run smoothly. He played no major role in the development

of the decision support system. He gave his full support to the group work.

The work group was composed of three planners from the Examination Department at the Ministry. There experiences from many years of work at the Department were extremely useful while testing the different programmes solving each sub-problem. The leader of this group has a central position in the development of the decision support system because as a previous teacher in informatics, he has sufficient background to understand also the technical aspects of the problem and to contribute to its solution. He was at the same time the leader and a user and developer.

Stakeholders were of course the directors and teachers from the different schools that were involved in the discussions about the purpose of the new system, the first tests and the final implementation. The feedbacks from the stakeholders were important during the tuning of the whole system.

The facilitator was my previous student who had developed the technical approach in his MSc thesis, afterwards he was hired as a consultant for the Ministry. He was the facilitator of the whole development and implementation processes. As we will see below other experts were involved. He will seek for the collaboration of the users, the stakeholders, and the experts at the different stages of the development and implementation of the system.

Other experts were: One system's designer from a consulting firm and three programmers hired at the Ministry.

7.4 The facilitation process

In this case study the facilitator has two main tasks:

- First, to design, develop and implement a computerized decision support system in close cooperation with the users and other experts. As described above a satisfying system was developed by decomposing the complex problem in a series of interrelated optimization sub-problems each of them being solved using simple, fast, and reliable heuristic methods. Here the facilitator is working as a scientist using rational approaches, mathematical modelling and algorithms to find satisfying solutions and using the scientific approach to manage the problem solving process.

- Secondly, the facilitation of the group work and the work of the experts in the development and implementation stages of the problem solving process. This was a long process, it started in 1991, was used for the first time in 1992, and has been running every year since 1993. The task of the facilitator was to develop an efficient and innovative form of work, a common culture, a positive way of solving conflicts and a creative manner of finding new ideas. Here, the facilitator is working as an artist, he is instructing, directing, and coaching people to be participative, collaborative and creative in the problem solving process. He is like an instructor of a play in a theatre, supporting the different artists to perform their best to create synergetic processes. Or, more metaphorically, he is like a painter were all the participants are his colours to be combined in shapes, shadows and forms to be able to create a master piece.

The technical approaches needed to deal with the above described complex situation are relatively easy to develop. Similar complex logistic problems have been previously solved using mathematical models and heuristics and special dedicated computerized systems.

The real complexity of the problematic situation in question is the social complexity related to the development and implementation of the system by the actors in a participative and collaborative way. It is very complex the management of these social processes. Here the manager, that is the facilitator, is not only a rational and intelligent decision-maker, but also a creative and artistic designer. This managing attitude, managing as designing, is found in architecture, art and design professions.

Of course as with any practical project there have been conflicts, delays, and other problems related to negativity of some of the users or programmers leaving the Ministry; but in spite of the facilitator's lack of practical experience, he and the leader of the working group believed that it could be done and were highly motivated to do the task. The system has now been used for 14 years in practice. This has been a great success. For the Ministry, the examination system is the most prestigious system since the examinations have intensive attention from the schools, the public and the politicians; if things go wrong, from the press! Fortunately most people, including many students and teachers, are not aware of the existence of such a decision support system.

8 Other Case Studies

The facilitation processes do not need to take so long time and not all problems have to be solved using mathematical models, computers and experts. The case studies shortly described below show real life problem solving were the facilitator was working as an educator, a scientist and an artist.

8.1 Community Facilitation (Whyte, 1996)

Noorvick is an arctic Eskimo community located somewhere in Alaska. The community is organised following the old traditions and some new ideas coming from the outside, the so-called developed world. The community has to deal with the authorities; located far away in a big city, in what concerns development, planning and transfer of resources. Many problems, conflicts and disputes had not been suitable solved. The result was misunderstandings and poor cooperation. These two cultures, Eskimos and public servants, were not able to communicate to each other. Meanwhile lack of work, lack of education centres, poverty, and resignation was the actual situation of the community.

One day a stranger, an artist, arrived to the community. He was a young man, who just finished his education in communication, filmmaking and video techniques. He did not want to make military service and applied to do some social work somewhere in the poor world. He expected to be assigned to some Caribbean island, to an on going project where he could use his artistic qualifications. The Eskimo community did not know about Tim's speciality and Tim did not know about the needs of the community. Tim was supposed to stay for two years.

In reality the artist knew nothing about Eskimo culture. Coming from a warm region, he

had to adapt to cold, snow and ice. He started learning some Eskimo language. He was a fast learner and his natural open-mindness to something new helped a lot.

After this first period, that probably took a couple of months, the artist became an explorer. He formulated the following questions: How can I contribute in the best way with my qualifications to the development of this community? Can I?

After some talks with the leaders of the community and some of the authorities he was able to identify the central problem: The lack of a constructive and cooperative communication between these two cultures. What ought to be done? Both parts were willing to do their best, but they did not know what to do. The lack of trust to each other was deteriorating the situation.

After some incubation time, one night the artist woke up after a fantastic dream. In his dream the conflict was dissolved and a fantastic cooperation between the community and the authorities had begun. He knew exactly what to do. It was 3 o'clock in the morning. He went to his working table and started outlining his ideas. By 6 o'clock he went to bed again, but he could not sleep. He was anxious to meet the leaders of the community to discuss his proposal.

His proposal was: To use the art of filmmaking and the video technology to solve the communication problem. The wishes, problems and ideas of the community would be filmed and sended as videotape to the authorities. The authorities would look at the videos and start a dialogue process to achieve consensus about some proposals.

The leaders of the community were positive about the idea, they wanted to give it a trial but a central question was formulated: Who was going to make the videotapes? The leaders concluded: it had to be the artist; he had the expertise. He did not agree he did not like the idea that the community would be depending on his expertise. What would happen when he leaves the community? The other problem was the language, the films had to be made in the local language and thereafter professionally translated to English, and he was not able to do it in the local language.

Some persons from the community were selected; they formed the group who was going to learn about facilitation, the art of filmmaking and video technology. To select the persons was not an easy task, all the people wanted to learn the art of filmmaking! The artist elaborated a textbook and a series of lessons and workshops. His education program was following two principles: learning by doing and dialectical thinking. The students were very fast learners and highly motivated.

To make the story short, here is the final evaluation: The artist's ideas and actions were a complete success. His students learned to make films to communicate the needs and problems of the community. In his final report he wrote: *The villagers had established ownership of the technology and learned how to facilitate discussions with other villagers and with the authorities.* He was happy but a lot still has to be done. He resided in Noorvick for 11 years.

8.2 The Vision Conference (Vidal, 2004a)

Nykøbing is a region in Zealand, part of the kingdom of Denmark. This region has a beautiful nature, nice beaches and many historical sites. During summertime there are too many people. During wintertime there are not so many people, only the old and the very young. There are

not so many possibilities for working or studying in this region. The administrators of EU consider this region vulnerable. There are many vulnerable regions in the whole Europe. The administrators want to support economically the development of these types of regions in the whole Europe.

Economical support was conditioned by the demand that the local people organise themselves in a NGO, including all the relevant stakeholders of the region. The wise people of the region created an organisation: DCO. Many wise and experienced people were involved. They found out that the region had very solid human resource capabilities and multidisciplinary know-how. The problem was how to develop visionary strategies, projects, and actions for the future that would push forward a sustainable development. Creative ideas and innovative projects were badly needed.

The director of DCO invited a multi-disciplinary visual artist for a meeting. The artist had developed a concept called Vision Conference, a combination of creative workshops and facilitation processes, arranged for a large group of people. The main purpose of such a conference was the creative production of visions, ideas and projects to innovate and develop a region or an organisation.

At the meeting the artist explained his work in elementary terms. He emphasised that he could be regarded as the instructor of a performance at an improvisation theatre or a leader of a jazz orchestra. He pointed out that his goal was to get the best of each participant in creative and collaborative terms. Finally, by the end of the meeting it was agreed to organise a one-day Vision Conference for the region. A plan for the conference day was outlined. Four of the artist's students were hired as facilitators and four persons from DCO were appointed as helpers to the facilitators. These last four persons should be the organisers of future conferences for the region.

The Vision Conference was an extraordinary experience for everybody. There were forty people; haft men halt women. It was like being part of a jam session, everybody playing a different instrument. It was at the same time chaotic and well planned. The four facilitators made a fantastic job guiding each of the four groups. A lot of energy was released; you could feel that at the plenary sessions.

In the morning, all the groups worked freely and collaboratively creating ideas for projects that could develop the region according to the guidelines elaborated by DCO. Quantity was demanded. During the afternoon, the groups selected some of the most promising ideas for further elaboration and design of an action plan. Quality was demanded. At the end, the artist made a short evaluation; he was very pleased with the performance of everybody. The participants were tired but very happy. Most participants had not before experienced situations were you were working seriously and having fun at the same time. Somebody remarked that this conference was a big exercise in creative communication.

Some days latter, the artist delivered a report with the achieved results, an evaluation of the whole conference and a list of tasks to be carried out by the leaders of DCO in their future strategic work. He ended his report with his favourite quotation*: Our task is to make the familiar strange and the strange familiar.*

8.3 Facilitation in a Firm

Rational, a modern consulting firm was located in Copenhagen. Three engineers started the firm twenty years ago. Now the firm employs more than thirty people with very different specialities. But they have something in common: They are highly qualified and super rational consultants. Rational is an international firm; they sell knowledge, know-how and analyses. Knowledge about the applications of IT and economic and technological analyses are Rational's specialities

At a meeting of the Board of Directors, where future strategies were discussed some concern was expressed about the fact that the firm and the employees were not very creative. They were very good solving problems in a rational way, but they were not good if creativity and innovation was demanded. One of the directors mentioned that in the future many of the tasks they would get would demand such qualifications. In addition, it was remarked that the employees were not very good at looking for new opportunities, new tasks, new costumers, etc. Moreover, the employees were not good working together in projects in a collaborative way; they had to learn to cooperate.

At the next meeting one of the directors informed that searching at the Internet; he had found a multi-disciplinary artist that was specialist in the facilitation of creative processes. Some firms had used him as an adviser with very positive results. Moreover, he was also giving courses about creative problem solving. It was agreed to invite him for a meeting.

During that meeting, the artist registered that the director was a very rational person, but he had a serious interest in visual art and music. The director was a collector, but he dared not to practice and develop his artistic tendencies. They agreed about starting slowly a kind of cooperation. Several meetings were planned where the artist would be a kind of adviser about how to introduce more creativity and innovation in the firm. The artist emphasised that he could teach the employees about artistic thinking to complement their rational thinking, and dialectical thinking in order to synthesise these two thinking modes.

Later, the artist participated in some projects as a mentor for some of the experts from Rational. A course was given for the employees of the firm focusing on management and the facilitation of creative processes. Both the artist and the director were very positive about this form of cooperation. Some of the employees were using creative tools in some projects. Moreover, the director and some of the employees discovered that the artist was also a painter, and some paintings were commissioned.

The director wanted to go further in the cooperation; he wanted to hire the artist full-time. The artist refused, he still wanted to have some time to paint, to make installations and sculptures. Then the artist proposed to the director to adopt his concept of Vision Conference as a way of working. He was interested in the idea that his concepts would be diffused to the whole world. Two of the artist's students, two engineers, were employed in the firm.

One Saturday in a nice hotel, a one-day Vision Conference was run for all the employees of Rational. The purpose of the conference was twofold:

- To learn how to organise such a workshop for a large group, and
- To discuss ideas for a knowledge policy for Rational.

The Vision Conference was both a failure and a success. The participants learned to plan, organise and carry out a Vision Conference. But they were not able to develop creative ideas and actions for a knowledge policy. They had too many mental locks.

Some days later, the artist was writing his final report. He outlined some suggestions of activities for the future specially focusing on knowledge management. He concluded*: The main condition for creative development is motivation of the participants.*

9 Conclusions

Everything can de approached scientifically and everything can become art. Our main message is that in what concerns problem solving in complex situations, it is advisable to use both the scientific and the artistic attitudes. More satisfying results will be achieved, the risk of failures will be minimized, all the participants will be empowered, and everybody will learn from the experience, even the facilitator.

In the case of the planning problem, the Ministry could have ordered the decision support system from a firm instead of in-house development. But in such situation the consequences of failure were too serious and could easily become a political issue. In Denmark, there are too many bad experiences with implemented computerized decision support systems that were extremely expensive to develop and implement and that did not solve the problem, on the contrary caused more problematic situations.

In the case study related to the planning of the examinations the facilitator was educated as an engineer, but in the social process he was managing he was an artist although he was not aware of that. He used his intuition to solve conflicts, supervised the experts and used time to dialogue with the users. He was able to create a common language, a common culture and motivate all participants. He was managing by designing.

In the other case studies, the facilitators were both professional artists and scientists, being able to use these complementary approaches when it was needed.

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