

Ludvig Stendal

# Learning about process control

Dr.ing.-thesis 2003:37

Faculty of Social Sciences and Technology Management  
Department of Industrial Economics and Technology  
Management



## **Preface**

This work is part of the INPRO research programme (Integrated production systems in the process industry) at the Norwegian University of Science and Technology. The aim of the programme has been to develop new knowledge about the multidisciplinary challenges regarding operations of process plants. It has involved a faculty of five professors and post graduate researchers and nine PhD candidates from three different departments – Engineering Cybernetics, Chemical Engineering, and Industrial Economics and Technology Management.

The programme has had a high degree of industrial involvement and has been funded by nine different associated process plants, the Research Council of Norway (NFR), the Federation of Norwegian Process and Manufacturing Industries (PIL), and the Norwegian Oil Industry Association (OLF).

I have been privileged to be a part of this group and to learn about the value of research and to learn much more about multi-disciplinary operations. Those I have learnt together with are Lisbeth Øyum, Mette Suzanne Husemoen, Karin Aslaksen, and Professor Morten Levin at the Department of Industrial Economics and Technology Management; Catharina Lindheim, Jahn Olaf Olsen, and Professor Christian Lien at the Department of Chemical Engineering; Jo Simensen, Kjell Støle Hansen, and Professor Bjarne Foss at the Department of Engineering Cybernetics; Professor Thoralf Qvale at the Work Research Institute, and Roger Klev at SINTEF, IFIM. Jorid Øyen and Tove Krokstad were central in helping us with the program. It has taken time for me to finish, but I would not have been without the valuable experiences with you!

The first one and a half year I was located full time in Trondheim and learnt to know colleagues in the program and not least my mentor Morten Levin. Thank you Morten for leading me through what is sometimes (often) felt as a chaotic mess to a PhD candidate. For practical reasons I have spent the rest of the research period located at my research site Tofte. Being located at the research site have certain benefits, but also the disadvantage of being apart from the daily informal contact with advisors and fellow students. On the other hand, I live rather close to the Work Research Institute in Oslo. This made it easier for my to meet

my co-advisor Thoralf Qvale. I am grateful for his interest in my project, for always having time for me, and not least for his feed back on my drafts especially on the theory section.

I would also like to thank Department of Engineering Management at Old Dominion University, Norfolk, VA for hosting me for three months in 1996. Especially thanks to Professor Fred Steier and Jane Jorgensen for arrangement and friendly contact for my family and myself. In a professors' busy daily life at University, our daily trips between Virginia Beach and Norfolk gave Fred and me also time to talk about Socio-technical systems and research.

At my research site Södra Cell Tofte I am grateful to a lot of people for helping me through this long lasting project. First of all to production manager Sverre Storebråen and personnel and organisation manager (now retired) Martin Gravdal for their involvement in the program and their belief in me to pull this through. Sverre has pushed me and at the same time given me opportunity to finish this work. Of all the others at Tofte I also would like to thank Hallstein Baarseth and Jan Gustavsen for interesting discussions. Especially Hallstein made it easier for me to be located far from the university.

Last but not least I have to say thanks to my wife Marit for taking more than her share at home when I have been physically and mentally occupied with this thesis. Three children and some challenges during these nine years surely have prolonged the time to finish this work, but I hope it has been worth the effort.

Nærnes, May 2003

Ludvig Stendal

## Table of contents

<b><u>PREFACE</u></b>	<b><u>I</u></b>
<b><u>TABLE OF CONTENTS</u></b>	<b><u>III</u></b>
<b><u>LIST OF FIGURES</u></b>	<b><u>VI</u></b>
<b><u>LIST OF TABLES</u></b>	<b><u>VII</u></b>
<b><u>SUMMARY</u></b>	<b><u>IX</u></b>
<b><u>CHAPTER 1 INTRODUCTION</u></b>	<b><u>1</u></b>
<b>1.1 TOFTE AND THE NEED FOR IMPROVEMENTS – LEARNING AS A VEHICLE</b>	<b>1</b>
<b>1.2 THE DEVELOPMENT OF THE RESEARCH QUESTIONS</b>	<b>3</b>
<b>1.3 STRUCTURE AND CONTENT OF THE THESIS</b>	<b>8</b>
<b><u>CHAPTER 2 PRODUCTION TECHNOLOGY AND ORGANISATION AT SÖDRA CELL TOFTE</u></b>	<b><u>11</u></b>
<b>2.1 INTRODUCTION</b>	<b>11</b>
<b>2.2 DEVELOPMENT AND CHANGES AT SÖDRA CELL TOFTE</b>	<b>12</b>
2.2.1 TOFTE IN THE LOCAL COMMUNITY .....	12
2.2.2 CHANGES WITH “NYE TOFTE” .....	13
2.2.3 MORE TECHNOLOGY DEVELOPMENT - THE TOFTE 350 PROJECT .....	14
<b>2.3 THE SULPHATE PULPING PROCESS AT SÖDRA CELL TOFTE</b>	<b>15</b>
<b>2.4 THE PRODUCTION PROCESS MORE DETAILED</b>	<b>17</b>
2.4.1 WOOD HANDLING .....	17
2.4.2 WET PULP DEPARTMENT .....	18
2.4.3 THE DRYING MACHINES .....	21
2.4.4 RECOVERY DEPARTMENT .....	21
2.4.5 INTERACTIONS BETWEEN DEPARTMENTS .....	23
2.4.6 PROCESS CONTROL SYSTEMS .....	24
<b>2.5 THE SOCIAL SYSTEM – HUMAN PROCESS CONTROL</b>	<b>27</b>
2.5.1 ORGANISATION STRUCTURE AND PROCESS CONTROL PRACTICE 1980 TO 1992 ....	27
2.5.2 “B-91” AND “LOOK 92” ; -DOWNSIZING, REORGANISATION, AND EDUCATION..	29
2.5.3 HOW THE “B-91” PROJECT CHANGED THE PROCESS CONTROL PRACTICE.....	32
2.5.4 EMPLOYEESHIP AS AN ORGANISATIONAL DEVELOPMENT PROJECT .....	40
<b>2.6 DEMANDS FROM THE MARKET . -TOFTE'S PRODUCTS, CUSTOMERS AND STRATEGY</b>	<b>42</b>
<b>2.7 SUMMARY AND FURTHER CHALLENGES</b>	<b>46</b>

---

**CHAPTER 3 A PROCESS PLANT AS A SOCIO-TECHNICAL SYSTEM** **49**

<b>3.1 DIFFERENT MODES OF PRODUCTION</b>	<b>49</b>
<b>3.2 CHARACTERISTICS OF A CONTINUOUS PROCESS PLANT</b>	<b>51</b>
3.2.1 PROCESS (VARIANCE) CONTROL .....	53
3.2.2 DIFFERENT OPERATIONAL PHASES.....	55
3.2.3 REPRESENTATIONS OF PRODUCTION EQUIPMENT AND SYSTEMS .....	57
<b>3.3 SUMMARY AND IMPLICATIONS</b>	<b>58</b>
<b>3.4 MAIN ASPECTS AND DEVELOPMENT OF SOCIO-TECHNICAL SYSTEMS</b>	<b>59</b>
<b>3.5 HISTORICAL DEVELOPMENT OF STS</b>	<b>62</b>
<b>3.6 ORGANISING FOR VARIANCE CONTROL</b>	<b>65</b>
<b>3.7 STS SUMMARY</b>	<b>69</b>

---

**CHAPTER 4 LEARNING SYSTEMS IN PROCESS PLANTS** **71**

<b>4.1 CATEGORIES OF KNOWLEDGE IN OPERATIONS</b>	<b>71</b>
4.1.1 LINKS BETWEEN DATA, INFORMATION AND KNOWLEDGE.....	71
4.1.2 DIFFERENT VIEWS OF KNOWLEDGE.....	74
4.1.3 KNOWLEDGE IN PROCESS UNDERSTANDING .....	77
4.1.4 ASPECTS OF KNOWLEDGE IN OPERATIONS .....	82
4.1.5 SUMMARY OF KNOWLEDGE IN OPERATIONS.....	85
<b>4.2 METHODS AND MODELS IN LEARNING</b>	<b>86</b>
4.2.1 CONVENTIONAL METHODS IN OPERATORS' EDUCATION AND TRAINING .....	86
4.2.2 EXPERIENTIAL (PROBLEM BASED) LEARNING .....	88
4.2.3 COLLECTIVE LEARNING.....	94
<b>4.3 LEARNING ARENAS</b>	<b>96</b>
<b>4.4 LEARNING TYPES RELATED TO DIFFERENT TYPES OF ARENAS</b>	<b>100</b>
<b>4.5 SUMMARY AND RESEARCH QUESTIONS REVISED</b>	<b>103</b>

---

**CHAPTER 5 RESEARCH METHODS** **105**

<b>5.1 INTRODUCTION ON RESEARCH DESIGN AND APPLIED METHODS</b>	<b>105</b>
<b>5.2 TYPES AND EXTENT OF DATA</b>	<b>106</b>
5.2.1 ROLES AND INTERACTIONS WITH SÖDRA CELL TOFTE .....	106
5.2.2 THE IMPORTANCE OF THE TWO FIRST PERIODS.....	108
5.2.3 THE THIRD PERIOD - EARLY THEORY DEVELOPMENT .....	109
5.2.4 THE FORTH PERIOD – EMPLOYEESHIP.....	113
5.2.5 THE FIFTH PERIOD – FINAL THEORY BUILDING.....	120
5.2.6 WORKING AS SHIFT MANAGER.....	124
<b>5.3 MY PARTICIPANT ROLE</b>	<b>124</b>
<b>5.4 THE CLAIM FOR VALIDITY</b>	<b>126</b>
5.4.1 PROLONGED ENGAGEMENT .....	127
5.4.2 PERSISTENT OBSERVATION .....	128
5.4.3 TRIANGULATION .....	128
5.4.4 PEER DEBRIEFING .....	129
5.4.5 MEMBERS CHECK .....	130
5.4.6 USE OF REFLEXIVE JOURNAL .....	130
5.4.7 TRANSFERABILITY.....	131
5.4.8 WORKABILITY AND CONCLUDING REMARKS .....	131

---

**CHAPTER 6 NEW ARENAS FOR LEARNING AT TOFTE** **133**

<b>6.1 INTRODUCTION</b>	<b>133</b>
<b>6.2 OPERATOR TRAINING</b>	<b>134</b>
6.2.1 BACKGROUND .....	134
6.2.2 THE INITIAL CONTACT AND EXPERIENCES FROM PETERSON LINERBOARD MOSS (PLM) .....	135
6.2.3 EXPERIENCES AND RESULTS FROM DEVELOPMENT AND USE AT PETERSON LINERBOARD MOSS .....	136
6.2.4 HOW TOFTE ADOPTED THE EDUCATION MODEL .....	137
6.2.5 STRUCTURE OF AN EDUCATIONAL PROGRAM .....	138
6.2.6. DEVELOPMENT AT TOFTE THREE AND A HALF YEAR AFTER THE INTRODUCTION OF OPERATOR TRAINING .....	139
6.2.7 OPERATOR TRAINING AS LEARNING ARENAS .....	142
<b>6.3 OPERATIONS WORKSHOPS</b>	<b>147</b>
6.3.1 BACKGROUND .....	147
6.3.2 STRUCTURE OF AN OPERATIONS WORKSHOP .....	148
6.3.3 EXAMPLES ON TWO SPECIFIC WORKSHOPS .....	152
6.3.4 OPERATIONS WORKSHOPS AS LEARNING ARENAS .....	157
<b>6.4 SUMMARY OF LEARNING ARENAS</b>	<b>159</b>

---

**CHAPTER 7 ANALYSIS OF TOFTE PRACTICE** **161**

<b>7.1 LEARNING SYSTEMS FOR WORKERS IN A PROCESS PLANT</b>	<b>161</b>
7.1.1 A CLASSROOM ATTEMPT .....	161
7.1.2 LEARNING TYPES RELATED TO OPERATOR TRAINING .....	162
7.1.3 LEARNING TYPES RELATED TO OPERATIONS WORKSHOPS .....	167
7.1.4 SUMMARY OF LEARNING SYSTEMS .....	176
<b>7.2 IMPLICATIONS FOR LEARNING OF DIFFERENT SOCIO-TECHNICAL STRUCTURES</b>	<b>177</b>
7.2.1 LEARNING ARENAS AND STRUCTURING OF TASKS .....	178
7.2.2 UTILISATION OF PROCESS OPERATORS KNOWLEDGE AND SKILLS .....	183
7.2.3 LEARNING ARENAS AS TOOLS IN STS DESIGN .....	187
7.2.4 LEARNING ARENAS AND IMPACT ON DEVELOPING DIRECTED LEARNING .....	190
<b>7.3 FURTHER DEVELOPMENT OF LEARNING ARENAS AT TOFTE</b>	<b>192</b>
7.3.1 TOFTE DEVELOPMENT 1998-2002 .....	193
7.3.2 ANALYSIS OF PRODUCTION STATISTICS .....	196
7.3.3 FURTHER DEVELOPMENT OF OPERATOR TRAINING .....	200
7.3.4 FURTHER DEVELOPMENT OF OPERATIONS WORKSHOPS .....	203
7.3.5 MORE ON ORGANISATIONAL AND MANAGERIAL FRAMES FOR FURTHER DEVELOPMENT OF LEARNING ARENAS .....	206

---

**CHAPTER 8 CONCLUSIONS** **209**

<b>8.1 THEORETICAL CONTRIBUTIONS</b>	<b>209</b>
8.1.1 CONTRIBUTIONS TO TOFTE AND PROCESS INDUSTRY .....	212
<b>8.2 THE NEED FOR FURTHER RESEARCH AND DEVELOPMENT</b>	<b>212</b>
<b>8.3 RECOMMENDED ACTION FOR TOFTE</b>	<b>213</b>

<b>A1. INPRO</b>	<b>215</b>
<b>A2. THE TOFTE 6-SHIFT CYCLE</b>	<b>217</b>
<b>A3. THE TRADE CERTIFICATE</b>	<b>218</b>
<b>A4. EMPLOYEESHIP</b>	<b>220</b>
<b>A5. INTERDEPENDENCIES BETWEEN “OPERATIONS” AND “MAINTENANCE”</b>	<b>223</b>
<b>A6. FEATURES AND CHARACTERISTICS OF A CONTINUOUS PROCESS PLANT</b>	<b>225</b>
<b>A7. ASPECTS IN VARIANCE CONTROL</b>	<b>226</b>
<b>A8. 8 OPERATIONS WORKSHOPS</b>	<b>228</b>
<b>A9. ACTION RESEARCH</b>	<b>240</b>
<b>A10. IMPLICATIONS FOR THE ROLE OF PROCESS ENGINEER AND UNIVERSITY TEACHING</b>	<b>244</b>

## REFERENCES

## List of figures

<b>Figure 2.1 Input / output representation of the Tofte pulp process .....</b>	<b>16</b>
<b>Figure 2.2 An overview of the Tofte plant .....</b>	<b>16</b>
<b>Figure 2.3 Organisation chart 1980 – 1992 .....</b>	<b>27</b>
<b>Figure 2.4 Production organisation structure, 1992 - onwards .....</b>	<b>32</b>
<b>Figure 3.1 Simple sketch of a plant consisting of unit processes.....</b>	<b>52</b>
<b>Figure 3.2 The enterprise as an open socio-technical system.....</b>	<b>60</b>
<b>Figure 3.3 A comparison between two organisational models.....</b>	<b>67</b>
<b>Figure 4.1 A MOPS representation of a continuous digester with side systems .....</b>	<b>72</b>
<b>Figure 4.2 The Kolb experiential learning circle.....</b>	<b>89</b>
<b>Figure 4.3 Experiential learning? .....</b>	<b>91</b>
<b>Figure 4.4 A process plant organisation.....</b>	<b>95</b>
<b>Figure 4.5 A cogenerative learning model .....</b>	<b>98</b>
<b>Figure 6.1 The phase structure in an educational programme.....</b>	<b>138</b>
<b>Figure 6.2 Schematic representation of an Operations workshop.....</b>	<b>149</b>
<b>Figure 7.1 Development in number of employees at Tofte.....</b>	<b>196</b>
<b>Figure 7.2 Development in production and capacity utilisation .....</b>	<b>197</b>
<b>Figure 7.3 Development in overall costs pr. tonne inclusive depreciation .....</b>	<b>200</b>
<b>Figure A4.1 Original Employeeship model.....</b>	<b>220</b>
<b>Figure A4.2 The Employeeship model at Tofte .....</b>	<b>221</b>

## List of tables

Table 2.1 Main events in the development of Tofte .....	11
Table 2.2 Composition of components in of wood / chemical pulp (%) for different species .....	17
Table 2.3 Department and year of change in control room systems .....	24
Table 2.4 Differences between Honeywell TDC 2000 and ABB Master .....	25
Table 2.5 End use of Tofte pulp in paper qualities (in %) .....	42
Table 2.6 The traditional method (Norske Skog Research) .....	44
Table 2.7 The new method. Control of fibre quality (Norske Skog research).....	45
Table 2.8 Selected points in Tofte's SWOT analysis.....	47
Table 3.1 A comparison of old and new paradigm of work (van Beinum, 1988) .....	65
Table 4.1 Two models in order to understand operators' work and competence demands .....	76
Table 4.2 Requirements for learning.....	100
Table 4.3 Adapting and developing directed learning.....	102
Table 5.1 Different research periods and roles in the Tofte organisation .....	107
Table 5.2 Reference group meetings.....	110
Table 5.3 Interactions and kind of data from the different Employeeeship events.....	114
Table 5.4 Employeeeship follow up activities .....	117
Table 5.5 Main interactions in the fifth period (May 97 – April 99) .....	121
Table 6.1 Organisation of learning departments and progress in development of phases, and of candidates (per April 2000) .....	140
Table 6.2 Operations workshops at Tofte in 1996, 1997 and 1998 .....	150
Table 6.3 Loss in tonnes (unbleached pulp -digester production) due to digester instability.....	154
Table 6.4 Oil consumption in kg per tonne of pulp.....	156
Table 7.3 Status of Operator training per October 2002. (Status per April 2000 in parenthesis).....	194
Table 7.4 Operations workshops 1998 – October 2002.....	195
Table 7.5 Development in percentage of off-grade products .....	198
Table 7.6 Tofte effluents; COD, AOX and Suspended solids (SS).....	199
Table A8.1 Capacity utilisation drying machine 3 .....	229





## Summary

The research site has been the Södra Cell Tofte pulp mill. The main focus in this thesis is how to learn about process control. The need for research on this theme is given implicitly in the foundation and construction of the INPRO programme. Norwegian engineering education is discipline oriented, and the INPRO programme aimed at integrating the three disciplines engineering cybernetics, chemical engineering, and organisation and work life science in a single PhD programme. One goal was to produce knowledge of modern production in chemical process plants based on socio-technical thinking.

In the introduction I outline how my research questions have been developed and the need for doing research in the field of improving process understanding in a continuous process plant. This thesis provides answer to the three questions:

1. What are the learning systems for workers in a process plant?
2. What is the implication for learning of different socio-technical structures?
3. How can learning be further improved for workers in the process industry?

In order to answer these questions and to provide a background for why these questions are important to Tofte, I describe and analyse the case plant Södra Cell Tofte. I find it necessary to make this part rather extensive in order for the reader to understand the context under which Tofte has been developing its learning arenas or learning systems. I use a socio-technical framework in doing this. I want to introduce and use this framework as I regard it as useful for one of my purposes with this work: Assisting the production unit at Tofte to improve learning. I go through technological improvements that have been carried out from 1980 onwards, and one major organisational change that has taken place. The downsizing and reorganisation that took place in 1992 is of importance as well as the organisational development effort named “Employeehip” that took place in 1996. I had a leave from the INPRO project for almost a year following and evaluating this particular project. The situation at Tofte in 1994 was lack of good learning systems, and after a major reorganisation in 1992 the organisation defined a need for better responsibility distribution and co-operation.

Chapters 3 and 4 present and discuss theories in order to give a broader background for the research issues in this thesis. In Chapter three I discuss features and characteristics of a continuous process plant as these have consequences on how knowledge and skills can be developed and why process understanding is a necessity. I present socio-technical system thinking (STS) as one way of regarding organisation and management of a process plant, and I further discuss why I find this approach appropriate for providing learning primarily at the shop floor level as an integrated part of daily production.

In Chapter four I argue that knowledge and skills in production are becoming increasingly important in highly automated remotely controlled process plants and develop a theory of “process understanding”. Process understanding is defined as *the ability to predict what is going to happen*. In order to predict what is going to happen with a system one firstly need to define the system boundaries. This system can then be regarded as a mental model. One must know and analyse input variables (know where and how to get relevant process information), and by this anticipate, like in a mental simulation, what will happen with the parameters within a defined time period. Different possible options may be mentally tested including what will happen if no corrective actions are taken. An ability to predict what is going to happen with the product, to process equipment or any other process variable, has to be developed and refined in order to operate a process plant optimally. Theories state that a variety of knowledge and skills are required and that some skills can be acquired only through years of experience. The “knowing why” within a process plant also has to be strengthened in order to develop a better process understanding, but as an addition to the experience based “knowing how”.

Models of learning regarding the demands given by the production systems in order to develop such process understanding are presented and discussed. These are conventional methods, experiential (problem based) learning, and collective learning. The experiential learning model is discussed and what may inhibit learning from experiences to take place in a plant. I have defined the concept “learning arena” and regarded each shift in a control room as a main learning arena since this is the place where theory meets practice. It is further discussed that practice will differ between shifts within same control room due to different mental models of the process. In various learning arenas, different communities-of-practice must be joined in order to make more shared mental models with the intention to align different practices.

In Chapter five the research methods used to explore the research questions, and thus to bring forth theories about gaining better process control, are reviewed. I have been inspired by action research methods in order to answer my research questions and to contribute in a necessary change process where development and use of learning arenas have been central. I have been more or less active in these arenas and played back experiences and theories in order to further develop the arenas. Besides participations in learning arenas, methods have been interviews, observations, and written documentations.

Chapter six is the case description of two different kinds of learning systems at Tofte: Operator Training (OT) - Operator based development and execution of education/ training and Operations Workshop (OW) - Problem based learning aiming at better production practice. I have provided background for the two cases as an answer to the educational challenges Tofte had in 1996 and not least to differences in operational practice between shifts. I describe background, characteristics, and development from what I term different learning arenas where the learning about process control will take place. I have also discussed in what ways these two learning systems can be regarded as learning arenas and briefly the kind of learning that can take place in each arena. In two Operations workshops I provide more details in order to show some strengths of the method.

In Chapter seven I provide answers to the three research questions outlined in the introduction and further refined in Chapter 4.5. I analyse how different learning types such as individual, experiential, and collective are covered within different learning arenas and how OT and OW meet the requirements for good learning systems in continuous process plants. Further I analyse how tasks regarding education and training are better distributed in a shift and day-time organisation with the two learning systems, and further how learning is integrated with working and thus process operators' knowledge and skills are better utilised. When I analyse the implication of learning of two different socio-technical structures, I also regard how managers are better enabled to become facilitators for learning. The two arenas have been well established at Tofte, but to a varying degree in the different departments. When regarding Operator training it is still too early to conclude on its impact on results in the pulp mill. However, two Operations workshops have made positive contributions and demonstrated the potential of the method. The strengths of the methods are the collective learning that place in cogenerated learning arenas. In Operator training this strengthens the

master-apprentice method, and in Operations workshops it gives a shared understanding and direction for further tasks in process control. Finally, based on the analysis of the first two questions I discuss how learning for workers can be further improved.

In Chapter eighth I conclude on my theoretical contribution and arguments for further research in the actual fields. Finally, based on my findings I will recommend organisational choices on future actions. STS provides frames and directions for learning to take place within groups along the production line. It is however not the scope of the STS paradigm to provide theories of what constitutes knowledge in operations of a plant. And the STS theories are not developed in order to cover more specifically models for how learning within and across semi-autonomous units and organisational levels may take place. Thus the main contribution of this thesis is learning theories based on two different kinds of learning models as means to develop process understanding.

# CHAPTER 1

## INTRODUCTION

### 1.1 Tofte and the need for improvements – learning as a vehicle

The Norwegian process industry is under a constant pressure to change due to changing external conditions. Increased globalisation, technology developments, new product demands, environmental demands from customers and authorities, and not least cost pressure, forces the organisations to be efficient and changeable. Norway's open economy and the development in our largest markets, the EU and the rest of Europe, will create an increased competition and make high demands on profitability in economic life in the coming years. (NOU 1991:4).

The process plant that is studied in this thesis is Södra Cell Tofte, a chemical pulp mill with a yearly capacity of 395,000 tonnes (2001). Tofte serves most of the domestic paper plants with sulphate pulp whereas 65 % is exported to European paper mills. The mill celebrated its 100 years anniversary in 1997 but was almost completely renewed in 1978-80 as a part of the restructuring of the Norwegian pulp and paper production. When the production equipment in pulp mills is almost identical all over the world, how then to stay competitive in a high cost country like Norway? With internal changes imposed by external pressure, the learning capacity of the organisations necessarily has to be increased. In this context Tofte in 1993 applied to the INPRO PhD programme (INtegrated PROduction systems in the process industry) in order to get extra research resources to the ongoing change process. (For more details about the programme, see Appendix 1).

The main focus in this thesis is how to learn about process control. The need for research on this topic is given implicitly in the foundation and construction of the INPRO programme. Norwegian engineering education is discipline oriented, and the INPRO programme aimed at integrating the three disciplines engineering cybernetics, chemical engineering, and organisation and work life science in a single PhD programme. One goal was to produce knowledge of modern production in chemical process plants based on socio-technical thinking. (Foss et al. 1995).

Large capital investments are put into chemical plants, hence operating them efficiently is of major concern. Requirements to operations are, however, becoming increasingly difficult to meet. The main reason for this are tighter quality bounds, resource awareness, higher demands on plant throughput, rapid changes in operating conditions, and the increased complexity of the plants themselves (Foss et al. 1995). The emphasis on knowledge and skills are stressed due to the high capital investments of the plant and often big economic consequences of faulty operations.

Arie de Geus, manager in planning department in Royal Dutch Shell is quoted in Senge (1990): *“The ability to learn faster than the competitors is probably the only lasting competitive fortune”*. Nonaka (1991) follow the same vein in the statement: *“In an economy where the only certainty is the uncertainty, the one sure source of lasting competitive advantage is knowledge”*. The highlight from top management on this is positive, but it will often be an espoused theory (Argyris & Schön, 1978) without a strategy to how to come around the structural constraints in a production plant. Human resource management often lacks understanding of the technology involved in production, and the engineers in production management often lack concepts of socio-technical system design (STSD) and a learning perspective on production.

Skule (1994: 8) argues that

*“One of the few who has attempted to put the relation between education and organisational learning on the agenda is Nordhaug (1990). However he too lacks of empirically grounded conceptualisation of organisational know-how and learning, and he also points out the need for in-depth case-studies on the outcome of education and training”*.

While Skule studied how vocational education for experienced workers influenced their skills in the food processing industry, my case study from Södra Cell Tofte covers how in-depth process knowledge can be obtained on top of and in parallel with vocational training leading to the certificate of skilled operator. This is due to the fact that the trade certificate covers only a fraction of the knowledge needed in order to control all the processes from one control room. In my research I will also focus on how knowledge and skills can be employed in order to improve existing and new technology and thus add to the needs Nordhaug identified.

Hendry (1996) states that learning theory should be placed more centrally within the theory of planned organisational change. Research is needed on how learning arenas can be created in order to learn from experiences from production, and also how new technology projects can foster learning, following the argument of Levin (1993) that technology development is organisational development.

This thesis is a contribution to the increasingly growing field of organisational learning. However, little research has been done in the field of investigating learning possibilities in a continuous process plant with its specific features and characteristics. Working, learning, and innovating are closely related forms of human activity, according to Brown and Duguid (1991). They are in conventionally thinking artificially separated (Hendry, 1996). Zuboff (1988:395) states:

*“As the intellectual skill base becomes the organization’s most precious resource, managerial roles must function to enhance its quality. The informed organisation is a learning institution, and one of its principal purposes is the expansion of knowledge-not knowledge for its own sake, (as an academic pursuit), but knowledge that comes to reside of what it means to be productive. Learning is no longer a separate activity that occurs either before one enters the workplace or in remote classroom settings. Nor is it an activity preserved for a managerial group. The behaviours that define learning and the behaviours that define being productive are one and the same. Learning is not something that requires time from being engaged in productive activity; learning is the heart of productive activity. To put it simply, learning is the new form of labour”.*

In this thesis I will discuss how Tofte has coped with this challenge and copied, adjusted, and created arenas where process learning may take place also in work situations.

## **1.2 The development of the research questions**

From the very beginning of the INPRO-project my fellow PhD students and I started the search and development of research questions related to our respective process plants. I had a point of departure given by Tofte. However, the development of the research question has been a long maturing and learning process between Tofte, the INPRO community, and myself.



Given the INPRO-perspective, my focus has been on the production department at Tofte. In hindsight, based on eight years of experience, I see that the problem fields I formulated were rather vague. The fields were about communication and information in the production department at Tofte:

- Between four different control rooms
- Between six different shifts
- Between daytime and shift organisation(s)

These are all relevant themes not only at Tofte. However, I never became confident with these fields when trying to find interesting research angles. From my INPRO-colleagues I also got feedback such as “interesting, but how will you do it?” and “where is the INPRO-perspective<sup>1</sup>?” I also got good advises as to how I should utilise my production and technological experience<sup>2</sup>.

During the summer and autumn of 1995 I reformulated the research field to possibilities for development of process knowledge in the production department. Information and communication are of course vital here as well. I had thus moved focus from better communication and information as an end to a means for development of improved knowledge about production technologies. I was at that time however not sure how to practically accomplish the research – how to make interventions in the plant? My research questions were at that time still open.

In order to participate in INPRO, it was a prerequisite that the plant had a development project that the PhD student could follow and do research about. In the case of Tofte, two different main projects emerged and turned out to be interesting possibilities. (I will return to these more in detail later in the thesis). The first one was an organisational development project called “Employeeeship” which was planned for during 1995 and executed in 1996 and

---

<sup>1</sup> By INPRO-perspective I mean both technological and social aspects. The critique was that I only covered the social aspects in my research proposal.

<sup>2</sup> I realised that finding useful and interesting research approaches about was not easily “given”, but a prevailing struggle with my self. This can also be regarded as a maturing and learning process as I have gained better insight in the field of organisational and socio-technical theories.

the first month of 1997. However, this project was on a general basis covering the whole organisation and was not coupled directly with technology change.

Except from general project goals, the production manager was the only person who had stated some partly measurable goals prior to the start-up of the courses. He expressed them at a Tofte internal conference where approximately 50 managers and union leaders were present:

- The process operators will be engaged and responsible for the development and conduction of training for colleagues. – Think in new terms.
- Check lists: All departments shall have and utilise up-to-date check lists.
- Propositions from employees: Revitalising. Involve operators in the evaluation of suggestions.
- Maintenance: Involve process and maintenance operators.
- Development of the plant: Active operators in development and improvement. Do not kill initiatives.

This list also serves as an analysis of Tofte's process control challenges. As the courses went on during the spring of 1996, many employees used the opportunity to stress the importance of follow up activities in a questionnaire survey. Some projects and activities that emerged summer of 1996 could be interpreted as follow-up activities related to the "wish list" from the production manager. I regard these follow-up projects, that will be presented and discussed in more detail later on, as "learning arenas". These were at the same time arenas where my research ideas about knowledge development in the production department could come through. My struggle at that time was how to make this action oriented. My solution turned out to be an action strategy in which I could support the activities where development of process understanding could take place; both in the arenas themselves and in working for managerial support.

The second main project at Tofte is called "Tofte 400" or just "T400". The investment frame is NOK 600 millions (1997) and technological projects will be conducted in most departments at the Tofte pulp mill in the period between 1997 and 2001 (the project also consist of market analysis, logistics projects, and product development). I follow Levin (1993) in his argument

that “*technology development is organisational development*”, and I searched for connections between how to organise for learning in the T400 project and the employeeship project.

The title of the thesis: “Learning about process control”, emerged during the fall 1997 when I became even more focused on the process technology learning perspective. “Learning about process control” is rather ambiguous and may lead to different interpretations. Three main categories of interpretations are:

1. Technical – e.g. learning about controllers, process dynamics, tuning of controllers, the technical artefacts, and so on.
2. Individual – learning how to operate the controllers via a computerised user interface and directly in order to avoid or control variations and disturbances in the process flows.
3. Organisational and managerial –learning how to organise and manage for production technology learning.

The focus of this thesis will be on points 2 and 3. The technological aspects will however be present as I discuss implications of process control in the organisation.

In order to learn more about process control and how it can be developed at Tofte, most of the research has been to follow and take part in the development and use of three main categories, which I will refer to as *learning arenas*, as these have been under development since summer 1996:

1. Operator training (OT)<sup>3</sup> – Operator based development and execution of education/training.
2. Operations workshop (OW) – Problem based learning aiming at better production practice.
3. T400 – Process plant development and project participation.

However, in order to focus on process control I have chosen not to report the T400 part as I then would have had to treat theory on project organisation and participation. It would then be

---

<sup>3</sup> MEDarbeider basert OPPl ring (Norwegian)

difficult to pull the threads together without exceeding the scope of this thesis. This will rather be suggested as an area for future research.

Based on the two first main arenas and Tofte's process control challenges, the following questions finally emerged:

How could Operator training and Operations workshops be means to develop better production knowledge? Would these be better means than other previous approaches? And what does production knowledge consists in? Thus my first general question turned out to be:

***What are the learning systems for workers in a process plant?***

Skule (1994) showed how the food processing industry struggled with utilising the newly educated, skilled operators. For the process industry, I will show that there are good possibilities for applying knowledge and skills in daily operations. However, a vast majority of process operators want to utilise and thereby further develop their knowledge and skills in addition to ordinary work tasks in quiet periods. In particular in a cost perspective are means to a better utilisation of knowledge and skills important. Thus in what ways are these arenas a means to better utilise operators knowledge and skills? A general INPRO goal was to develop knowledge based on socio-technical thinking. When regarding Operator training and Operations workshops in organisational and managerial frames, the second main question became:

***What is the implication for learning of different socio-technical structures?***

Based on experiences with learning arenas I will discuss how the arenas can be improved and also how synergies and interactions can be utilised. I will also discuss the organisational and managerial context at Tofte and how this may be changed in order to improve the outcome from the arenas. This introduces the question of

***How can learning be further improved for workers in process industry?***

I regard the whole production section as the unit of analysis, but I will tend to have a focus on the process operators as they "push the buttons" and thereby need all the knowledge and skills

they can get. However, when operators' tasks are changed, other people's tasks will change as well and these will also be discussed. In Chapter 3 and 4 theories will be presented and discussed in order to give more background for the questions.

### **1.3 Structure and content of the thesis**

In this chapter I have outlined how my research questions have been developed and the need for doing research in the field of improving process understanding in a continuous process plant. In the following I will give a short description of how the thesis is structured and to the content of the individual chapters.

In Chapter two I will describe and analyse the case plant Södra Cell Tofte. I find it necessary to make this rather extensive in order for the reader to understand the context in which Tofte has been developing its learning arenas. In doing this, I will use a socio-technical framework, which will be elaborated on in the following chapter. I want to introduce and use this framework as I regard it as useful for one of my purposes with this work: Assisting the production unit at Tofte to improve learning. I discuss technological improvements from 1980 onwards and one major organisational change that has taken place. The downsizing and reorganisation that took place in 1992 is of importance, in addition to the organisational development effort named "Employeeeship" that took place in 1996. I had a leave from the INPRO project for almost a year, following and evaluating this particular project.

In Chapter three I will discuss features and characteristics of a continuous process plant as these have consequences on how knowledge and skills can be developed and why process understanding is a necessity. I present socio-technical system thinking (STS) as one way of regarding the organisation and management of a process plant, and I will further discuss why I find this way of regarding an organisation as appropriate for providing learning primarily at the shop floor level as an integrated part of daily production.

In Chapter four I will argue that knowledge and skills in production are becoming increasingly important and develop a theory of "process understanding". I will discuss models of learning regarding the demands given by the production systems in order to develop such a process understanding and introduce the two terms *community-of-practice* and *learning arenas*. At the end of the chapter I will discuss and refine my initial research

questions given in the introduction by the new insights I have gained based on the theory reviewed.

In Chapter five I review the research methods used to learn more about my research questions and thus to bring forth theories about gaining better process control. I have been inspired by action research methods, both to answer my research questions and to contribute in a necessary change process where development and use of learning arenas have been central. I have been more or less active in these arenas and played back experiences and theories in order to further develop the arenas.

Chapter six is the case description of Operator Training (OT) – Operator based development and execution of education/ training and Operations Workshop (OW) – Problem based learning aiming at better production practice. I describe background, characteristics, and development from what I term different learning arenas where the learning about process control will take place. In two Operations workshops I provide more details in order to show some strengths of the method.

In Chapter seven I provide answers to the three research questions outlined in the introduction and further refined in Chapter 4.5. I analyse how different learning types such as collective, experiential, and individual are covered within different learning arenas and how OT and OW meet requirements for good learning systems in continuous process plants. Further I analyse how tasks regarding education and training are better distributed in a shift and day-time organisation with the two learning systems and further how learning is integrated with working and thus process operators knowledge and skills are better utilised. When I analyse the implication of learning of two different socio-technical structures I also consider how managers are better enabled to become facilitators for learning. Finally, based on the analysis of the first two questions, I discuss how learning for workers can be further improved.

In chapter eighth I conclude on my theoretical contribution and make suggestions for further research in the actual fields. Finally, based on my findings, I will recommend organisational choices on future actions.

In Appendix 1 I have provided more details about the INPRO-programme. Further I have appendices on Toftes' shift cycle, the craft certificate, an organisational development

programme, interdependencies between “operations” and “maintenance”, features and characteristics of a process plant, aspects in variance control, brief reports from eight Operations workshops, a short description of action research, and finally implications for the process engineer role and university teaching.

## CHAPTER 2

### PRODUCTION TECHNOLOGY AND ORGANISATION AT SÖDRA CELL TOFTE

#### 2.1 Introduction

In this chapter I will present and analyse the case plant Södra Cell Tofte to give a background for use and development of the learning arenas that will be presented and analysed in Chapters five and six. I will use a socio-technical perspective (Emery and Thorsrud, 1976, Trist 1981) when I analyse the technological and organisational changes that have taken place at Tofte. This analysis will shed light on the relevance of my research questions at Tofte. The chapter will therefore end with a summary that will provide the reader with a better understanding of Tofte's process control challenges. How some of these are handled are the themes for the remaining part of this thesis.

Table 2.1 shows main events in the development of Tofte. The table will also serve as headlines in my analysis. Given the topic of learning about process control, I will tend to focus on themes and events relevant for this purpose.

**Table 2.1 Main events in the development of Tofte**

Year	Event	Background
1897-99	Foundation and construction of Tofte pulp mill based on sulphite.	
1907	Foundation and construction of Hurum pulp and paper mill, sulphate method.	
1978-80	Construction of Nye Tofte.	Structure rationalisation in the Norwegian pulp and paper industry. Secure wood supply.
1982	Bankruptcy.	Technical problems, marked decline.
1989	Tofte 350 – technology development.	Environmentally driven. New effluence permission. Increase in capacity in order to finance the project.
1990	Start of process control systems change and new architecture in control rooms.	Unreliable electrical circuits. Problems with service and spare parts.



1991	“B-91” –Downsizing and reorganisation.	Too high costs compared with competitors.
1992	“LOOK 92”.	Need to raise general competence in organisation.
1996	“Employeeeship”.	Organisational development.
1996	“Tofte 400”.	Driven by cost reduction: Minimum investments to maximise production without doing major changes in main equipment. Improvements of quality and environmental effluents.
2000	Sold from Norske Skog to Södra Cell in Sweden	Focus strategy in Norske Skog

The production development at Tofte can also be read from Figure 7.2 in Chapter 7.3.2. Tofte is now a medium sized producer of market pulp in Europe. Since the start up of “Nye Tofte” in 1980, the production has risen from 248,000 tonnes in 1984 (the first year with full production after a bankruptcy in 1982) to 379,000 tonnes in 2001<sup>4</sup>.

## 2.2 Development and changes at Södra Cell Tofte

In this section I will describe main events and development at Tofte. I start by giving a short historical background and also of the place Tofte as a “company town”.

### 2.2.1 Tofte in the local community

The plant Södra Cell Tofte is situated at the place Tofte in Hurum municipality. Geographically Tofte is located at the tip of the Hurum peninsula surrounded by the Drammen fjord and the Oslo fjord. The road distance to the nearest cities Drammen and Oslo is 45 km and 70 km, respectively. The industrial tradition at Tofte started in 1897. The first pulp was produced on 20 March 1899, and the first production capacity was 8,000 tonnes of sulphite pulp<sup>5</sup>. 6 years later another pulp mill was built 1.5 km distance from Tofte<sup>6</sup>. The place has thus been developed as the

<sup>4</sup> When Nye Tofte was started in 1980 it was the biggest sulphate pulp mill in Europe.

<sup>5</sup> Due to developments and investments the production rose to 92,000 tonnes in 1969, which was the best production year. At Tofte there was no recovery of the black (spent) liquor (lignin, some hemicellulose and inorganic chemicals). In 1929, however, Tofte began to produce ethanol from the spent liquor and this production reached a peak in 1972 with a production close up to 6,000 cubic metres.

<sup>6</sup> Another plant located in Tofte is the Hurum papermill. Today it is a paper mill with special grades and a production capacity of 30,000 tonnes. From 1906 to 1956 it was a pulp mill, and from 1956 to 1980 it was an integrated mill

need for labour at the two plants changed. The mills were located at Tofte a hundred years ago because of close access to resources as water-based power and clean water to the production, access to wood, and ice-free harbours for shipments of pulp and for access to logs transported by sea.

In 1999 the number of employees at the Hurum paper mill are 125 and at the Tofte pulp mill 365. Approximately 1,500 people live in Tofte, and a majority of the employees live in the vicinity of the two plants. As the major workplaces “everybody” either work or have relatives or friends connected to the plant(s). Organisational changes therefore to some extent will affect the local community as well as the plant. In this respect Tofte is similar to other single site places in Norway with one (or in this case two) dominating work place and shortage of alternative industrial work places. The youth has to travel to Drammen or Røyken (35 km) for upper secondary education.

### 2.2.2 Changes with “Nye Tofte”

The biggest change in the plant’s history, and thereby in the place Tofte, came in 1978 when it finally was decided to build a (almost completely) new plant as a part of the structural rationalisation in Norwegian pulp and paper industry<sup>7</sup>.

The plant is built around a naturally and partly man-made bay. When the new plant was built in the period 1978 to 1980, there were several restrictions on the design choices, since existing equipment and some of the buildings were to be kept in order to reduce the investment costs. The total investments were NOK 1.6 billions (1980). The changes in technology from the old plant to the new one were drastic. The size increased from a maximum production of 91,000 tonnes of pulp to nominal capacity of 250,000 tonnes. The pulping principle was changed from the sulphite

---

based on the sulphate process with both pulp and paper production. This mill recycled most of the chemicals and utilised the dissolved organic material. In August 2002 the plant went bankrupt.

<sup>7</sup> In Norway up to the seventies, there were a number of smaller pulp mills. Most of these were based on the sulphite method with no or little recovery of cooking chemicals and dissolved materials from the wood. The Norwegian Government through the Norwegian Pollution Control Authority meant that it was necessary to cut drastically the pollution from the pulp mills to rivers and lakes, and at Tofte, the Oslo fjord. Most of the mills were smaller units and rather unproductive and could not take the necessary investments in order to comply with the demands from the Government. The Hurum pulp and paper mill needed investments, and it was decided to stop the pulp production and be served by the new plant at Tofte in the future. At the same time personnel from the Hurum mill who was familiar with the sulphate production technology could apply for new jobs at Tofte.

method to the sulphate method, and the digesting principle was changed from seven batch digesters to two continuous digesters one for normal sized chips and one for a smaller fraction of chips. A completely new chemical recovery plant was built. At the “old” Tofte some of the spent liquor had been utilised in ethanol production while the rest of the extracted wood and cooking chemicals were dumped in the Oslo fjord. As pulp production on the new plant was doubled compared to the two old plants, emissions to sea went down from 280 tonnes/day of COD in 1975 to under 70 tonnes/day with the new plant. Suspended solids (fibres) went down from 28 tonnes/day to below 1). A new chlorine-alkaline plant was built based on membrane technology. This plant served Tofte with chlorine gas and sodium hydroxide from 1980 to 1992. What was kept from the old plant was two drying machines from 1961, a filter bleach plant based on elemental chlorine, and the boiler house with a steam turbine. Another major change took place in process control technology. This topic is treated in Chapter 2.4.6 “Process control systems”.

### 2.2.3 More technology development - The Tofte 350 project

The development in production can be seen in Figure 7.2. A major environmental concern in the 1980s was emissions of chlorinated compounds. In order to respond to new external demands initiated by environmental concerns from the Norwegian Pollution Control Agency, it was impossible to carry on with the existing bleaching equipment. A new bleach plant had to be built. At the same time it was decided to increase the capacity of the plant to 350,000 tonnes.

Besides the new bleach plant the following main technological modifications were performed:

- The older filter bleach plant from 1953 based on elemental chlorine stopped
- The chlorine-alkaline plant from 1980 was closed
- A new drying section on the drying machine 3
- More heating surface in the recovery boiler
- Higher vaporisation capacity

In the following I will describe the main production steps used by Södra Cell Tofte in order to produce chemical pulp. I will start with the purpose of pulping and thereafter the main equipment systems in the pulping process before I describe and analyse how the pulp mill is controlled by the social system.

### 2.3 The sulphate pulping process at Södra Cell Tofte

At Tofte the value addition is to transform Norwegian spruce and pine and eucalyptus imported from plantations in Africa and South America into fibres, which in turn are used, to a various degree, in different paper mixes and qualities. As such, Tofte is a typical process plant with only one main product, but with different qualities.

A tree consists of various cells and molecules. The products from Tofte are the purified fibres in the tree. Such fibres have a remarkable capability to create strong network structures and pure fibres are colour free (white). These are the two main customer desired features of sulphate pulp. The wood fibres are made of large, long chained molecules named cellulose and hemicellulose. Fibres are hollow and they have a multi-layer fibre wall, which is only 0.003-0.01 millimetres thick. The wall has openings and “valves” which serve the vertical and horizontal transport system in a tree. The fibre wall is impregnated with lignin in order to create stiffness. In spruce and pine (softwoods) the fibres are in the range from approximately 2 to 3 millimetres long and 0.04 millimetres thick. Hardwood fibres such as from eucalyptus are shorter, being in the range from 0.7 to 0.9 millimetres long and 0.02 millimetres thick. Hence the names long- and short-fibred pulp. In addition to the lignin within the fibre walls, the fibres are “glued” together with lignin giving the tree trunk necessary strength to be standing up straight and carry the branches, sprigs, and leaves.

The purpose of the sulphate pulp production at Tofte is to extract as much as possible of the 42 % average content of cellulose and the major part of the 28 % average content of hemicellulose in the conifer wood. As much as possible of the remaining wood which will be 27% lignin and 4% resin, is removed to give the pulp the desired qualities.

Raw material, like round timber and saw mill chips, are transformed into market pulp via the following steps: Wood handling - cooking - washing - screening- bleaching – post-screening - drying - packing. In addition comes a recovery line consisting of evaporation - chemical recovery - cooking liquor preparation. Figure 2.1 shows an input-output schematic representation of the main process steps in the production and Figure 2.2 gives an overview of the plant where the different departments are located.

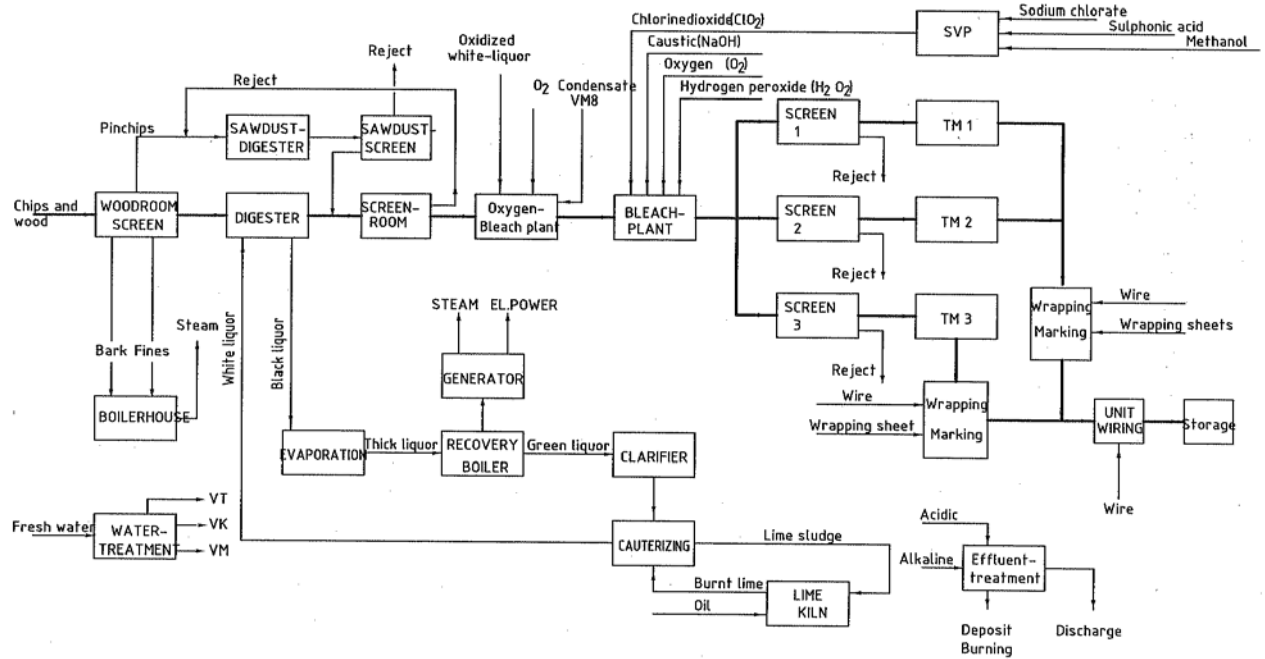


Figure 2.1 Input / output representation of the Tofte pulp process



Figure 2.2 An overview of the Tofte plant

A sulphate pulp mill thus consists of several highly different main production steps located in separated departments. To give an impression of the amount of devices in use, the Tofte pulp mill has 1,280 mechanical production devices besides pumps, 650 pumps, 360 tanks, 2,500 electrical drives, and 4,100 control loops.

Pulp production is a compromise between gain from the wood and desired pulp properties. Too hard cooking will remove more lignin, but at the same time even more hemicellulose and cellulose. In order to produce pure non-coloured (appear as white) fibres and a strong pulp, as much as possible of the remaining lignin has to be removed and at the same time as much as possible of hemicellulose and cellulose in the fibres must be retained in order to increase strength properties and yield. A pre-bleach plant based on oxygen removes another 1.5% of the lignin without any major influence on the cellulose, while a main bleach plant will at last remove some lignin and destroy the rest of lignin molecules so that future colour effects in the end use of paper are prevented. The final pulp content is given in Table 2.2.

**Table 2.2 Composition of components in of wood / chemical pulp (%) for different species**

	Spruce	Pine	Eucalyptus (globulus)
Cellulose	42 / 82.5	41 / 82.5	47 / 82
Hemicellulose	28 / 17.5	28 / 17.5	26 / 18
Lignin	27 / 0	27 / 0	25 / 0
Extractives	3 / < 0.1	4 / < 0.1	2 / < 0.1

## 2.4 The production process more detailed

In this section I describe the production steps in the Tofte continuous sulphate pulp mill. The four headlines follow the layout of the plant.

### 2.4.1 Wood handling

Domestic logs are collected at two wood terminals (Lier, west of Oslo and Ljan, east of Oslo, both at the seaside). The logs arrive at the terminals by truck or train. The terminals serve as intermediate storage, before transport to Tofte by barge. Sawmill chips are also transported from Lier to Tofte by barge.

Some of the log supplies come directly to Tofte from the west and south coast of Norway by ship. Some truckloads are also received directly to the mill. Spruce and pine round timber has to be barked and kept separated through the wood room and then stocked in separate chip piles until they are used in the production of long fibre pulp. In addition there is a separate stockpile for sawmill-chips.

Eucalyptus logs arrive at Tofte from South America and Africa by ship and is pre-stocked on the quay as bundles. Chipping is made according to a specified combination of bundles from various types of eucalyptus wood and is stocked in separate eucalyptus chip-piles.

There are two separate parallel lines for the handling of softwood and hard wood. All processes in this department are mechanical and open for visual insight. During the chipping processes at Tofte and at sawmills, chips of varying sizes are produced. In order to have a stable pulping process and to get stable high quality, the chips must be screened. In the chip screen plant, oversize chip and pin chips are separated from the main chip stream to the digester. The oversized chips are passed to a re-chipper. In order to utilise a maximum of the raw material, the pin chips are passed to a special screen where the fines are separated and passed to energy production together with bark in a bark boiler. The pure pin chips is cooked in a separate digester line.

Since the processes are mechanical only (barking and chipping), they can be stopped and started whenever needed without causing any quality losses. However, a higher production rate and a new homogenisation chip pile (from 1998) will require a more stable and continuous production.

The main purpose of the department is to deliver chips of equal size in correct chip piles. Another purpose is to feed a bark boiler in the recovery department continuously with dried (pressed) bark from spruce and pine.

#### 2.4.2 Wet pulp department

In the wet pulp department, chips and pin chips are transformed into bleached pulp. The wet pulp department can further be divided into three departments with different production characteristics:

- Continuous digesting
- Pulp washing and screening
- Bleaching.

A pre-planned mix of chips is continuously fed into two continuous boilers. Roughly 10 – 15 % of the chips are of the size of matches and are fed into a pin chip boiler, while the rest is fed into the main digester. Some process steps take place before the chips enter the main digesters. The chips have to be impregnated with the cooking liquid, which is an aqueous solution of sodium hydroxide and sodium sulphide. Steam is added in order to get the proper temperature for the chemical reactions to take place and enough pressure to impregnate the chips all through. The pressure in the system is raised from atmospheric to 9 bars (at the top of the digester) via two special rotating valves. The continuous digester utilises a method called “isothermal cooking” or ITC, where the purpose is to balance the temperature in the digester as much as possible. During the cooking process, the cellulose fibres are released from the lignin matrix surrounding them, and with ITC a maximum of lignin is released at a moderate temperature in order not to keep up the yield of cellulose and hemicellulose. The fibres become soft and can fall apart when the pressure is reduced to atmospheric pressure outside the bottom of the digester.

The main clue in this process is to cook the pulp to a desired level of residual lignin (termed kappa number) and to keep the kappa number constant at this level in order to avoid disturbances in downstream processes and thus give quality deviations and unnecessary consumption of bleaching chemicals.

The “products” from the digesters are the pulp which now is brownish in colour, some uncooked residuals (especially knots), sand and smaller stones, dissolved material from the chips, and the inorganic spent cooking chemicals sodium and sulphur. These products are then further transported to the next section, which as will be shown, is partly integrated in the digesting processes.

The cooked pulp is washed and screened in a double screen system in order to minimise the content of impurities. The screen reject, such as knots and uncooked parts of chips, is returned to the pin chip digester, together with fresh pin chips. The pin chip pulp is washed, screened, and added for re-screening in the main pulp stream. The reject from the pin chip screen is removed from the process.



In the screen room, a defoamer is used to control the foam formation in pulp lines and filtrate tanks. And sometimes dispersants are used to prevent build-up of deposits. Washing and screening are important factors for the final quality and the overall economy. In order for the pulp to be as clean as possible before bleaching, effective washing is required. However, too much water added has a negative economic impact since the spent cooking liquor must be evaporated in the recovery department.

The bleaching department may further be divided into three sub departments: The oxygen pre-bleaching plant, the main bleaching plant, and the chlorine dioxide department. In the oxygen bleach plant, the residual lignin content (measured by “kappa number”) is further reduced by means of oxygen and sodium hydroxide (oxidised white liquor). In this stage about 40 % of the residual lignin is removed, washed out and recovered together with the dissolved wood substance from the cooking. Further bleaching is made by using chlorine-dioxide in three separate bleach tower stages with an intermediate oxygen and hydrogen peroxide-enhanced alkaline extraction stage between the two first tower stages.

The bleach plant is controlled in order to reach a brightness of ISO 90<sup>8</sup>. The brightness of the bleached pulp depends on chemical charge, pH, and temperature during the bleaching steps. The bleached pulp is led to one of the three storage towers, dependent on pulp grade. (Short fibre, long fibre grades or a mix between them). Dispersants are used to prevent pitch deposits. The level of residual chlorine is controlled and removed by addition of an aqueous solution of sodium dioxide. The final pH in the pulp (customer demand) is controlled by use of sodium hydroxide (NaOH).

Common for these departments is the chemical and mechanical treatment of the fibres and the separation of the main product from lignin and impurities. Yet the three sub departments are all different with regard to the main production equipment. The three sub departments which make up the wet pulp department are highly integrated as washing water flows counter current from the bleach plant in the direction of the digester (the bottom of the digester is in fact the first washing step). The three sub departments must in many respects be controlled as one unit.

---

<sup>8</sup> International Standard Organisation. Degree of whiteness in per cent compared with a standard.

### 2.4.3 The drying machines

From the storage tanks, the pulp is pumped through one of two alternative pipelines to either of three drying machines. Before entering the machines the pulp passes screens in order to remove physical impurities. The first two “TM 1” and “TM 2”, are based on hot air drying of the pulp web (fan-drier), while “TM 3” is a drum-drying machine with an additional fan-drier that was added in 1991. The two smaller drying machines, TM 1 and 2 each have a nominal production capacity of 200 tonnes per day. They “survived” when the new plant was built in 1980, while TM 3 was new in 1980. The capacity of "TM3" is about 1,000 tonnes per day.

In principle, the drying process is simple. What takes place is reduction of the water content from 90 % in the storage towers to 10 % in the finished product. While simple in principle (water removing), pulp drying requires advanced control and skilled, experienced personnel.

Before entering the drying machines, the wet pulp goes through a final purification unit. In the first section of a drying machine the pulp suspension is diluted to 3.5 % before it is distributed on a horizontal web where water is removed by gravity and vacuum. In the next section the pulp still supported by webs is pressed through rollers. When leaving the last couple of rollers, the web is dry and strong enough to enter the final steam drying section.

After the drying process, the pulp web is cut into sheets, piled into bales of 250 kg, pressed in a baling press, wrapped, wired, and marked in either of two packing lines. A batch of 8 pulp bales is stacked into 2000 kg units.

The important quality measure is purity and the remaining moisture in the pulp, which is to be kept constant at 10 % water content. Variations in the rest moisture content will give varying sizes of the bales and this may cause handling problems and dangerous situations in addition to giving customers a bad impression of the product.

### 2.4.4 Recovery department

In the recovery department the spent cooking liquor (black liquor) from the two digesters is converted into a new cooking liquor (white liquor), while the dissolved wood substance (lignin and some hemicellulose) is transformed into steam and electric power.

The liquor line consists of various stages and also here widely different production steps, both internally in the recovery department and compared with the other departments at Tofte. Firstly the thin liquor (black liquor) is converted to thick liquor by evaporation of added water (condensed steam in the digesters and added washing water). This process takes place in a series of evaporation steps where heat economy is a major task. The product from this process is termed thick or black liquor. The amount of dry solid is about 72 %. It is a production goal to keep the dry solid at this level and as stable as possible.

The resin content in the chips reacts with sodium in the cooking liquor to soap. If not treated properly, this soap that floats on top of the liquor in the two liquor tanks in the evaporation department may cause serious foaming problems. The soap is thus treated with sulphuric acid in a separate pine oil plant and sold as a by-product.

The next step in the recovery process is the recovery boiler. The boiler serves two important purposes: it partly transforms spent cooking chemicals into new chemicals, and the organic material from the wood is combusted and transformed into thermal (steam) and electrical energy.

At a more detailed level, the thick liquor is burned in a reducing atmosphere in the bottom of the recovery boiler, resulting in a smelt of sodium sulphide, residual sodium sulphate, and sodium carbonate. In the upper section of the boiler, an air surplus provides a complete combustion of the dissolved wood substance. The furnace is surrounded by water and steam tubes in order to cool the furnace walls and to utilise the energy. High-pressure steam from the recovery is reduced to medium pressure and low-pressure steam in a turbine, which runs a generator with a capacity of 40 MW. The clue is to get enough heat down in the boiler to sustain the endothermic reduction from sulphate to sulphide. The efficiency of the boiler is measured as the degree of this reduction reaction. The smelt from the soda recovery boiler is dissolved in weak liquor and turned into green liquor. The green liquor now consists of sodium sulphide, residual sodium sulphate, and sodium carbonate. In addition there will be various kinds of impurities, such as some unburned carbon and a number of inorganic chemicals, which will circulate through the plant.

Another unit, the bark boiler, is burning bark and fines. When the plant is in stable high production, the recovery and bark boilers supply all necessary steam and electric power to the plant. The steam consumption is 350 t/h and the electric power consumption is about 30 MW

(electric power consumption is equivalent to consumption in 10,000 Norwegian homes). This department also includes the water purifying plant for production of mechanically purified water and chemically purified water for the pulp process and de-ionised water for the boilers.

In the causticizing section the sodium carbonate is to be converted into the cooking chemical sodium hydroxide. The green liquor passes a special purifier before it is converted into white liquor in the causticizing plant by reaction with lime. Lime sludge (calcium-carbonate) is separated from the white liquor in a filter, then washed and burnt to new lime (burnt lime) in the lime kiln by means of oil-firing. Also in the lime kiln, odorous gases from the digester and the evaporation are burnt. This gives an energy surplus in addition to combustion of the odour-yielding components. A minor part of the white liquor is oxidised in a separate unit for use in the oxygen bleach plant.

I have provided descriptions of the various production steps, and tended to show the diversity between the four departments. I will now proceed the technical description with interactions between the departments in order to show more of the complexities that have to be handled by the social system.

#### 2.4.5 Interactions between departments

The Tofte pulp mill is controlled at the operating level from four control rooms. However, as shown in Figure 2.3, there are mass and energy flows between the four main departments as well as within the departments. The representation is simplified and shows only the main streams. What is not shown are all the internal interactions and physical feedback loops that exist within each main department. Physical feedback loops within a department and between departments makes a plant more complex to control. What may seem to be an optimum solution in one department may give negative impact in another department. One example is the use of washing water in the digesting department, which is positive with regard to later chemical consumption in the bleaching department, but which has a negative economic impact in the vaporisation department where extra steam must be used to remove the extra water. Pulp washing can also be used to exemplify a more complex process control. This kind of integration is not shown explicitly in Figure 2.1. In the drying machine department chemically purified water from the recovery department is first heat exchanged and thereafter used for a final dilution of the pulp. The pure water from the drain and press section are collected and used in the bleach plant for

final washing and dilution. The washing takes place concurrent of the fibre movement. The first washing step in fact takes place inside the digester itself as the bottom is constructed as a concurrent washing zone. This example of integration in order to conserve energy is at the same time an example of an important environmental effort. By using the washing water concurrent to the product movement, emissions to the sea are highly reduced. This is shown in table 7.2<sup>9</sup>.

I have this far presented the main production steps and some interactions between the departments. I have not yet treated the process control hardware and systems in order to control the pulp mill both at a control room level and at a plant level. This will be the topic in the next section.

#### 2.4.6 Process control systems

The old plant was until 1978 operated manually and with locally placed pneumatic controllers. In 1980 the new plant became equipped with state-of-the-art remote automatic control of instruments, the Honeywell “Total Display Control (TDC) 2000” and electrical motors with Siemens Programmable Logical Circuits (PLC) electrical control. Both field instruments and motors were now remotely controlled from four different control rooms<sup>10</sup>. Because of an increasing rate of failures in some PLC circuits and improved availability of process representation possibilities, it was decided to change systems in the entire plant in a stepwise manner. ABB was selected as vendor and the changes started in 1988. The physical controllers, measurement instruments, valves, motors, and cabling to controlling units were kept, while the input/output units and the logic units were changed. The process operators got new tools with the new interface. Table 2.3 shows department and year of change, while Table 2.4 is a comparison between Honeywell TDC 2000 and ABB Master/Advant.

**Table 2.3 Department and year of change in control room systems**

Department	Year
Wood chipping	1988
Chlorine dioxide plant	1989
Bleach plant	1991

---

<sup>9</sup> In fact, Tofte is the third best pulp mill in Europe with regard to low emissions to sea and without an external treatment plant.

<sup>10</sup> Such a change is the topic in Zuboff (1988): “In the age of the smart machine”.

Digesters and screening department	1991-92
Pin chip digester	1993
Vaporisation plant	1995
Causticizing and pine oil	1996
Recovery boiler and steam turbine/generator 2	1997
Drying machine nr. 3	1997
Boiler house and process water treatment	1998
Drying machine nr. 1 and 2	1999

**Table 2.4 Differences between Honeywell TDC 2000 and ABB Master**

	Honeywell TDC 2000 Siemens S3 PLC	ABB Advant ABB master
Instrument control and motor control	Separate systems	Integrated systems
Process representation	8 controllers as bars in a group picture	Flow sheet representation
Opportunities for advanced control (programmed algorithms)	No	Yes
Representation and use of interlocks	On paper form only.	Integrated in the system. How each controller is interlocked and its present condition is shown by choosing that option.
Learning support	Minor	Shows placement of equipment in the process

With ABB, both motors (for pumps, gears, propellers) and controllers are operated from the same system. With TDC 8 controllers were represented as bars with a set point and the corresponding process value in per cent on each image on the operators' monitors. The new system enabled flow sheet representations of the production equipment. Another factor is learning support. It is easier for newcomers to place the various controllers and motors in relation to each other when having them represented directly on the monitors and thereby easier learn new systems. With the new systems it also became possible to have a more advanced control of selected processes. At Tofte major parts of the chip digester and the bleach plant can be put in an advanced process control mode. Another major change is the representation of interlocks. Earlier this was on paper forms only. With the new system, a selection can be made on any controller and motor to see if the

equipment is interlocked, how it potentially is interlocked and a real-time status update. With the introduction of ABB, the control rooms were redesigned with the operator stations physically much closer to each other than in the plant from 1980. While in the earlier system the representations were restricted to one or two monitors, the processes now can be controlled from any operator station within a control room. The flexibility is thus increased.

In 1984 Tofte installed an information system called MOPS or “Mill wide Optimisation and Information System” in parallel to the process control systems. Monitors were installed in each control room and in the office of the shift manager. All measured signals from the processes are gathered in a database and made available graphically and in reports. Pictures and reports have since 1984 been optional with additional possibilities of making graphical representations of production equipment and departments. In 1999 58 different pictures and 167 reports are available. All on-line measurement signals are available as trend curves and/or reports. Manual laboratory analyses are fed into MOPS reports and made accessible to operators. Figure 4.1 shows the MOPS representation of the continuous digester and surrounding equipment. With the expansion of personal computers and the integration of PCs in plant wide networks, MOPS in 1990 also became available on every PC throughout the plant. This means that everybody have the possibility to monitor what is happening everywhere in the plant at any given time. With MOPS the information function of automated control (Zuboff, 1988) is utilised.

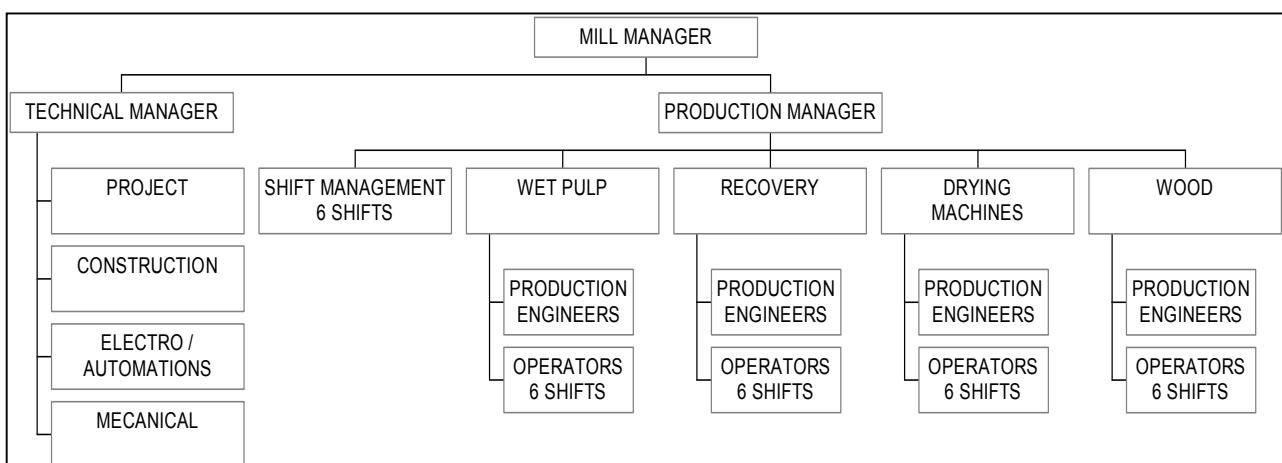
This far I have looked at the technical systems of the Tofte pulp mill. I will now proceed with the social system, and how the new technologies affected the qualification demands, represented by the new process control system in 1980. I will then proceed with how the technical systems are controlled by the production organisation.

## 2.5 The social system – human process control

In this section I will describe and analyse the social system at Tofte and restrict this to the production department. A major downsizing and reorganisation took place at Tofte in 1992. The project was called “B-91”<sup>11</sup>. This project had impact on process control and learning possibilities, and is therefore central in this thesis. First I present the organisation and some process control practice from the startup of the redesigned plant in 1980 as a background for the project, and proceed with the main changes in the project and how practice was changed after the project in the period of 1992 to 1996. In 1996 a new project called “Employeeeship” was conducted (Chapter 2.5.4). My interventions in the organisation started with this project. I will therefore give a background for the project and describe it briefly. I will end this section with a presentation and discussion of Tofte’s strategy, and sum up with process control challenges that Tofte still (in 1996) had to cope with. These challenges will serve as an introduction to the theoretical discussions and to the learning arena cases.

### 2.5.1 Organisation structure and process control practice 1980 to 1992

In 1980, the new plant was designed for a traditional organisation which was functionally divided and followed a mechanistic structure. Production and maintenance were divided in two separate departments. Each functional department had a vertical hierarchy with foremen, group leaders, and department leaders.



**Figure 2.3 Organisation chart 1980 – 1992**

<sup>11</sup> “B-91” = “Bemanning-1991”. “Bemanning” (in Norwegian) = Manning.



The production department was divided in time by 6 shifts<sup>12</sup> and a daytime organisation in each production department. Each department; wood handling, wet pulp, drying machines, and recovery -had a local management consisting of department leader, production engineer(s), a foreman, and in two departments (recovery and wet pulp) also an instructor.

The personnel responsibility for the process operators was given to each local department manager. Operators at the same shift then had four different managers. The shift management consisted of a shift manager and an assistant. The shift management was in principle in charge of production beside daytime. The shift manager had the information tool (MOPS) to stay informed about the whole production line and thereby co-ordinate the production according to the situation in the different departments.

The production manager, shift manager, and laboratory personnel were located in the same building as the wet pulp control room. The laboratory was also a centralised unit under which 3x6 shift laboratory technicians were organised.

“Nye Tofte” represented new technologies, in particular with central control rooms with remote process control and control signals represented on monitors. To many workers this new way of working became too difficult, and they gave up their work as process operators. The first two years of production was characterised by many technical problems, especially with electrical control. In combination with a market decline, this led to bankruptcy. On the other hand, all these start and stop situations gave valuable practice for understanding the plant and how to handle practically stop and start situations, even today it represents valuable core competence, particularly in the recovery department.

Because of the differences in main production equipment between physically divided departments, and also due to the local production management, the control of the different departments was undertaken in different ways. In the first years after the start up in 1980, reliance on technical expertise, such as production engineers, was high. This reliance was especially

---

<sup>12</sup> Tofte in 1980 chose a 6-shift cycle that is repeated every sixth week. Responsibility for a given department thus has to be shared between at least 6 persons. Tofte's shift cycle is shown in Appendix. 2. Every sixth week in the cycle is off, while every fifth week is disposable (cover up for absenteeism, courses, holidays, and so on). A local study has shown that based on 5 % absenteeism, only 8 days during a year is free for project work and education. What originally may seem to be plenty of time for developing work in practice amounts to very little. In present practice the disposable operators are used as task forces doing clean up in various departments.

strong in the wet pulp department. When major trouble occurred, daytime personnel such as foremen and production engineers were often contacted to solve the problems. When the shift personell did not have to take responsibility for controlling the processes during unstable operations or in start/stop situations, they had less chances to learn from experiences and the reliance upon the engineers expertise endured. When to leave responsibility to the local department manager and when to keep it himself was far from clear, and the safest solution was to call for help.

Within each control room there was a hierarchy between screen operators and field operators and the practice of “one man one job” prevailed. When an operator reached the highest position, it was difficult to move him or her and thereby the possibility for others to learn new jobs was restricted.

All maintenance: mechanical, electrical, instrumentation, and constructions were centralised entities, but the staff had dedicated entities for which they were responsible. Since all maintenance was organised separate from production, different views of priorities arose. Mutual accusations between “operations” and maintenance often occurred. It was clearly a “we – them” culture given by the organisational structure. The internal maintenance functions developed well and became renowned for its systems of preventive maintenance. The education of apprentices within maintenance disciplines was also regarded as good, and the degree of trade certificates within the maintenance disciplines reached 100 % during the 1980.

### 2.5.2 “B-91” and “LOOK 92” ; -Downsizing, reorganisation, and education

In 1990 it became clear to the Tofte management that other similar Nordic mills were manned with far less people than Tofte, especially green field sites. None of the technological modifications and developments at Tofte, had involved manning adjustments or any changes in organisational structure. At Tofte, the process control practice, especially in the wet pulp control room had been dominated by management control. This practice to a large extent removed the responsibility for troublesome situations from the shift operators and shift management, and thus also their learning opportunities. The production manager, which was closely connected to the wet pulp department and one of the main architects of what should be the new organisation structure, saw that it was not beneficial to continue the existing practice, as production staff had become more experienced and skilled over the past ten years. The other main reason for the

structural changes was the sub-optimisations that occurred between operations and maintenance, and that more decisions could be taken at the shop floor. It was a wish from the top management at Tofte to change that practice.

When the project was planned, the economic results were positive. But knowing the cycles in the pulp market, negative results were expected (and were very soon experienced). Thus it was natural to explain the forthcoming changes with the necessity to reduce future costs.

In March 1991 the employees and the local community was informed by Tofte's top management that a new organisation and manning plan had to be developed. The official statement of the project was:

*“Tofte is to have a manning that in number, competence, motivation, and composition is at least as effective as the best pulp plants in Norway, Sweden, and Finland, our physical situation taken into consideration”*<sup>13</sup>.

### **The main changes**

619 persons were employed at Tofte in 1991 and 152 employees had to leave. The biggest structural changes took place in the production department.

Major changes were:

- The shift manager position was upgraded and he got the personnel responsibility for the shift staff.
- A splitting and decentralisation of the maintenance function to the production departments.
- The foreman layer in production and maintenance was to a large extent removed and authority and responsibility were transferred to the operator level.

---

<sup>13</sup> The latter part was a demand from the trade union as the placement of the different production departments at the plant and the state of the technological lay-out (eg. three drying machines instead of one) made Tofte uncomparable with a green field site.

A central idea was to place the shifts as main production units in the centre, and that other departments had service functions for the shifts. What happened at Tofte also happened in several other Nordic mills at that time. As Lundquist (1996:55) reports:

*“Reason for organisational changes have mostly been due to drastical reduction in manning (often with several hundred persons) due to the marked decline in the beginning of the 90s. The plants have been strongly influenced by old traditions. Organisations have been hierarchical and controlled by top management. Common for all projects were fewer levels; responsibility and authority down to the operating level, whose engagement is to be increased.”*

### **Some effects of the changes**

As the major work place in the small community Tofte, the down sizing was very hard to tackle. Those who were in charge of conducting the processes had to live side by side in the small community with all those who had been directly or indirectly affected. Through 95 years and even through the bankrupt in 1982, the work places had been regarded as safe. Now this suddenly was changed and the wounds took long time to heal. As late as in 1996 the operators' trade union leader wrote in a speech: *“It was time to leave the word (B-91) that everybody hated in the past and start looking forward”* (IR: Borgersen, 1996).

The downsizing did not result in any trials. The operators' trade union kept a rather low profile as they had not shown any willingness to discuss any natural downsizing earlier, which had been practice in many other Norwegian plants in the same period. However, the lack of preparation for some of the changes was criticized, e.g., some operators that initially lost their jobs were asked to return to work at the mill.

The biggest opposition against the changes came from the department of mechanical maintenance. Pasmore (1988:5) states:

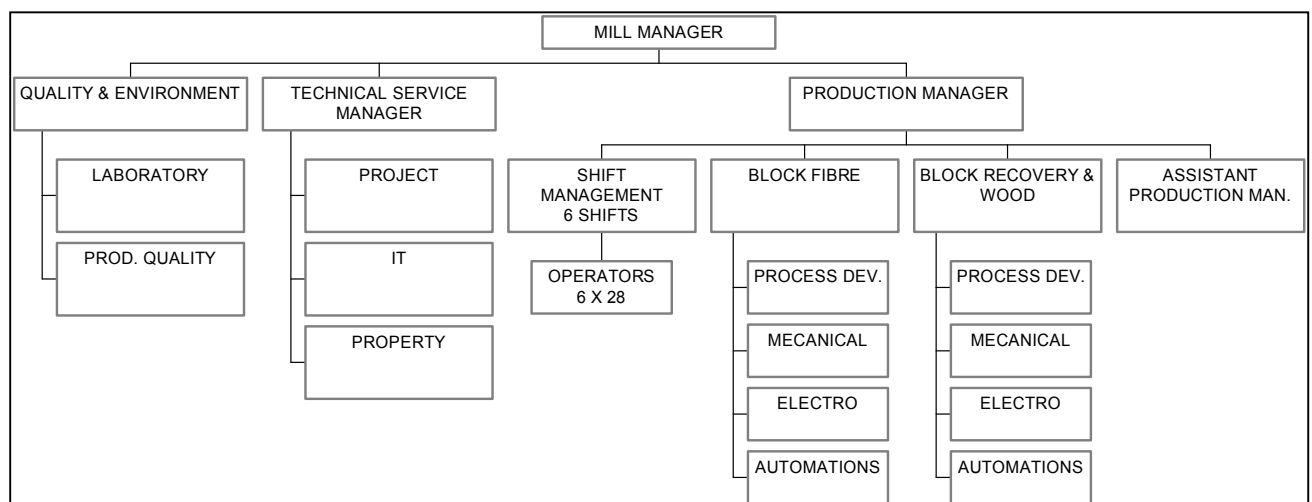
*“Thus for an organization to introduce changes in the design of work, it must change agreement among people; but because agreements are vested with historical meaning, attempts at change often meet with resistance. Therefore, in addition to recognising the need to change, organizations must also pay attention to the process of changing. New agreements must be understood and accepted before they result in improved organizational effectiveness.”*

The new agreements were neither understood nor accepted. The distribution of maintenance to the departments was delayed and was finally forced through by the top management. The mechanical operators should now manage the work more independently as they were dedicated to certain areas of responsibility and also have a co-ordinating function whenever extra help was needed since the foreman function was removed. The heavy resistance may be explained by unwillingness to split a maintenance organisation that internally was regarded as good. The internal flexibility also to a large extent disappeared. A central maintenance unit, however, was kept in order to serve the distributed units with specialised tasks, such as welding when necessary. At a Tofte seminar in 1997, the problem was still present to some degree: *“We know what to do, but we do not get the work done”*<sup>14</sup>.

### 2.5.3 How the “B-91” project changed the process control practice

In this section I will describe and analyse the development in the production section with emphasis on the major changes that took place in 1992. The given analysis will also serve to give an understanding of later projects.

The new organisation structure can be illustrated with the following figure.



**Figure 2.4 Production organisation structure, 1992 - onwards**

<sup>14</sup> This was a plenum presentation from a group work at a Tofte seminar at Bolkesjø in November 1997.

### **Production manager and production planning**

The production manager's tasks changed in many ways due to the major reorganisation. He was now in charge of maintenance as well, as this was organised in the production department. The division of responsibilities between shift managers and the production departments also became more clear.

A main strategic task is production planning. At Tofte this is performed by the production manager. Based on a long-term plan, Tofte budget a yearly production based on market demands and the availability and price on wood. This budget is further divided into campaigns for one year at the time. One week before the actual production, the production manager meets the market manager, and they plan the amounts and qualities for the next 14 days. A production schedule, which refers to internal procedures (ISO)<sup>15</sup> on how to produce the specific quality, is then made. In addition he gives feedback on the market situation, specific projects, and what to focus on in the next 14 days. The wood mixture and amounts of different pulp qualities are also given in this document and so is the desired production rate. The 1999 budget is based on 90 % capacity utilisation<sup>16</sup>, and this demands a high throughput, and thereby high availability on production equipment.

### **Shift management tasks and responsibility**

A major change was the upgrading of the shift management function. A new qualification demand was a university degree in engineering or equivalent. A major task would be more concentration on plant optimisation as the various sub-processes at Tofte must be controlled according to each other, and it is impossible for a single process operator to have this overview. (See "Interactions" in Chapter 2.4.5).

The shift manager became responsible for the production according to the schedule specified and given by the production manager. He thus has the full production responsibility at his shift, delegated from the production manager. He is assisted by one shift manager assistant, two mechanical operators, one electrician, two laboratorians (one at the final product control and one taking process analyses), and 21 process operators located in four different control rooms. This also implies that he is responsible for the professional development of 27 persons.

---

<sup>15</sup> Tofte became accredited to the International Standard Organisation (ISO) 9001 in 1994.

<sup>16</sup> Capacity utilisation is a measure based on last year's unbleached pulp production on the two continuous digesters. 90 % capacity utilisation means that the production volume at the 35. best day of 350 is used as budget goal.

Differences in time between the shifts, and between most shifts and the daytime organisation put certain demands on communication and information. The main daily production co-ordination and planning activity takes place at a morning meeting where the production manager, shift manager, and production department managers are present. The shift manager is in charge of the meeting. Events and deviations from each shift are reported and form a basis for the information in shift changes. These reports based on last day's production from 7 a.m. to 7 a.m. are used at the meeting. Responsibilities for different activities concerning operation and maintenance are discussed and distributed, and deviations from production parameters are explained by the shift manager. The production manager writes a report from the meeting that later on is distributed to all control rooms and to the staff in the production departments. Based on the meeting, the shift manager informs operators about potential changes that are required, e.g., small local stops to do maintenance. The department managers inform their respective departments about events from the last 24 hours shift reports and meeting discussions, and inform their managers about actions that may need to be started right away or later. At the end of the day, a summary meeting is held in the two production departments. This serves as feedback on what has been done during the day and what will be planned for further. If there is a need for smaller stops, e.g., next day, the shift manager can plan for that during the night by utilising the buffer capacity in storage tanks.

### **Process operators' tasks and responsibility**

Most of the process operators experienced big changes after "B91", as personnel responsibility was transferred from the production departments to the shift manager. The operators thereby always have their manager present instead of the earlier practice, which involved 25 % of the time during daytime shifts. In the redesigned organisation, the shifts were encouraged to solve problems more independently. The foreman function did no longer exist and the former production engineer should no longer "automatically" rush in and try to solve all production problems. This meant that the shifts had to take more responsibility, and thus increase their learning. In order to operate and control the departments more independent of production engineers, it was also encouraged within each control room to rotate more between jobs than had been common practice before the reorganisation. A skill-based pay system was introduced to encourage for this development, and more emphasis was also put on formal competence. It was a precondition for those process operators who did not possess a trade certificate<sup>17</sup> that they would

---

<sup>17</sup> Description of a trade certificate is given in Appendix 3.

start the education as soon as possible in order to keep their job in the new organisation.

However, this demand was not completely followed up on.

The production is controlled from four main remote control rooms. In the following I will shortly describe the various tasks within a control room. In a pulp mill there are, as previously described, several interactions between the control rooms. In addition there are many interactions between production sections within one control room as well. These interactions need to be handled by the operators in close co-operation.

#### Wood handling manning and tasks

At present six operators operate the wood handling department. Three are dedicated to transport of logs and chips as drivers of various vehicles, while three are dedicated to a combination of control room monitoring and control, fieldwork, and operating a crane.

Originally in 1980 six persons operated the department. When eucalyptus was to be produced continuously in 1994, and later on this was increased to seven and later on (1999) reduced to six as the need to distribute chips in piles were reduced with a new homogenisation chip pile.

#### Wet pulp manning and tasks

Five process operators control the wet pulp department. One is in charge of chips feed and the two continuous digesters, one is in charge of pulp washing and screening, while the third is in charge of two bleaching plants. In addition there are two field operators; one at the unbleached side (digesting, washing and screening), and one at the bleached. The number of operators in this department remained unchanged from 1980 until 2001. In 2001 the wet pulp operators took over the shift laboratory tasks. The number of operators is by this change six. When a new operator is recruited, at least one of the field jobs have to be mastered before he or she can start to systematically learn the to control the processes from the operators stations.

#### Drying machine manning and tasks

The department is manned with five operators. One is controlling drying machine 1 and 2 and also their wiring and wrapping, one is controlling drying machine 3 and the sedimentation basin. One operator is in charge of field jobs on the three machines. One operator is required to monitor and assist when needed on the mechanical wiring and wrapping. The adjacent control room to this section is separated by one store. The fifth operator transports the units to the local storage before it is shipped to terminals in Europe or transported by trucks for domestic use. Until 1997



there was another field operator, and thus one dedicated to the main drying machine and one to the drying machine 1 and 2.

#### Recovery manning and tasks

In this department the manning was reduced from seven to five in 1992. The evaporator and causticizing field is a combined job. There is no designated field operator, and while one operator is doing fieldwork, the other has to monitor the processes from the central control room. To the recovery boiler and steam turbine there is one control room and one field operator. The bark boiler, oil boiler (only used under start up and stop and during severe trouble), water purification plant, and a smaller steam turbine (8 MW) is controlled by one person in a separate local control room, but while in automatic mode, all processes may be monitored and controlled from the central control room, and thus give more flexibility.

#### **The production departments**

In the production departments the personnel responsibility for the process operators were handled over to the shift managers and the production foremen function was removed. The four production departments; wood, wet pulp, drying machines, and recovery now became “process” and maintenance departments as the maintenance functions were decentralised and the staff got new local offices in the different departments. Remote maintenance shop floors were also built in connection to the process departments. The departments “own” the process equipment, and the tasks are to serve the production shifts with reliable equipment and thus perform preventive maintenance and necessary repairs. Locally placed shop floors are an important means to develop closer contact between operations and maintenance. As the department leader no longer had the personnel responsibility for the operators, more emphasis could be put on the development of the technical standard of the department.

Production engineers changed titles to process engineers and work content was changed at least to some degree. They were now supposed to work more on long-term projects and also more with process optimisation and leave more of daily operations to the shifts. Other tasks would be production analyses, written procedures and routines, flowsheets upgrading and other documentation. They were also in charge of education material and assisting the education of operators. The process engineers were unsatisfied with this task due to the lack of structure of educational material. The responsibility for apprentices was also unclear. The practical work, and typical “fire fighting” were supposed to be handled by the shifts. However, as the co-ordinating

function between operations and maintenance was removed, the process engineer, at least in a transition period after the reorganisation in 1992, became co-ordinator in order to make the production running.

### **The education project “LOOK-92”**

The reorganisations created new and unknown tasks for a number of employees from one day to the next. A slimmer organisation also demanded a more multi-skilled work force. A precondition for the reorganisation was that the remaining work force had to strengthen its vocational competence. This was also a precondition from the operators’ trade union for accepting the new organisational plan. There was thus agreement and a wish in the whole organisation for further education.

An organisation can choose to start educational efforts prior to a change or it can wait until the changes are made and thereby easier see who needs what kind of knowledge. At Tofte the last alternative was chosen. All education was organised in a separate project called “LOOK 92”<sup>18</sup>. The programme goal was as follow: *“LOOK-92 will give the employees at Tofte the necessary competence to make Tofte as cost effective as the best Nordic pulp mills”*.

The goal was ambitious, and an ambitious plan was made to cover each individual in the organisation:

- Develop work descriptions for all work positions
- List knowledge demands in all work positions
- Specify the knowledge demands
- Gap analysis - judge each person’s knowledge against the demands in the position - map the need for education
- Make priority of the demands - make an education plan
- Develop educational material and programmes according to plans
- Conduct the programs
- Develop a system for competence registration in order to follow up.

It was an active period with courses of various kinds. However, 80 % of the process operators were unsatisfied with the education connected to “B-91” (Øyum, 1994). For the process

---

<sup>18</sup> Læring, Opplæring Og Kompetanse. In English: Learning, Training, And Competence.

operators, problems began already with the gap analysis. The process operators themselves had to make the gap analysis and it was indeed difficult to specify what they did not know or were uncertain about<sup>19</sup>.

After “B-91” two instructor jobs were removed, and the responsibility for the education of apprentices and operators were given to the process engineers in the different departments. It soon proved that the complexity and amount of work to be done was clearly underestimated as no progress was made. When “nye Tofte” was built in 1980, there was a lot of documentation, but this documentation was not easy to use as information was distributed in different books and it was difficult to get an overview. The project “LOOK 92” was meant to represent a “security” for operator instruction and training after the downsizing in 1992 in the “B-91” project. The organisation and personnel department in charge of the project was not themselves able to judge how education practically could be implemented for the process operators, and it seemed to be particularly difficult to implement in the shifts. For some reason the “LOOK 92” model for the process operators was regarded as viable because the amount of resources dedicated to the task were not sufficient. However it is not the scope of this thesis to elaborate more on the decision making process behind “LOOK 92”.

Despite the problems regarding the conduction of the education in the shift organisation, the changes regarding shift management and operators have been reported to be the most successful (Øyum, 1994). As posed by a wet pulp operator: “*I could never have worked under the old control regime*”. The changes experienced by many operators, especially those who were unsatisfied with previous practice, can be explained by more fulfilment of the psychological job demands (Emery, 1972). In a complex process plant, which in addition is under constant technological development, the need to learn can be satisfied for a large group. This was also strengthened as the operators were in a much larger degree supposed to take their own decisions regarding production.

---

<sup>19</sup> In the spring of 1994, some months before I entered the INPRO-project, I was employed to write the instruction material for the recovery boiler department where I had been a production engineer in the period of 1988-91. I was constantly concerned whether and how that material would come into use, and I tried as best as I could to have much self-instructions and co-operation with the process engineers in the department. I was well aware that it would take resources to manage and conduct the training, and the instructions were, as I feared, stored in a shelf. Nothing more happened before another chemical engineer was employed during summer of 95 to develop instructions in the causticizing department. This material had the same fate as mine and it was almost forgotten as the person was only temporarily employed.

During the “B-91” process more focus was placed on the first line workers, and thus the shift organisation was to operate more independently and handle internal variances both within each control room and between the four control rooms. A shift may thus be regarded as a semi-autonomous unit where process analyses and quality analyses are performed on shift, and results immediately are fed back to those in charge. Two mechanical and one electrical maintenance worker are also present at each shift. Various kinds of failures are thus sorted out at the shift before they cause major disturbances in the process, and qualified decisions can be made whether more maintenance staff must be involved.

At Tofte autonomous practice in control rooms mostly is restricted to process control, following schedules given by the production manager and followed by the shift manager. Thus the shift managers’ practice is of importance regarding development of process control. At Tofte there are six shift managers, each with their individual managerial style. Whatever style, each shift manager is dependent on the operators’ ability to make decisions within their department. It is completely impossible for the shift manager to have detailed process control. Development of the operator’s knowledge and skills is thus a major managerial task. A means to achieve this was the encouragement to rotate within a control room in order to learn the different jobs and thus obtain redundancy of functions. The shift manager also is in charge of accepting an operator in a position. The criteria for when an operator is ready to operate a new sub-department has been unclear and subject to when the operator self have reported that he / she is ready. This situation did not improve since the education programme “LOOK 92” failed for the process operators.

However a higher level of multi-skilling within control rooms have developed. Internal redundancy within each shift has increased. The process control ability and also the handling of start/stop situations have increased. However, there were still different practice regarding process control between shifts within same control room. This is in fact a major process control challenge since such changes will impose more deviations in many processes and make a department more difficult to operate optimally.

The changes in organisational practice was also accomplished by changes in the process control systems. This started in the wet pulp control room. According to the new bleach plant, thorough education and training had been given, and the new plant was equipped with new integrated control of both instruments and electrical drives. In 1992, the digester and screening department

followed, and in 1993 the control room was changed so that the operators were moved physically much closer to each other, and the monitors were grouped in a semi circle around a table. The new flexible technology, which allowed screen based flow-sheet representation to be transferred between monitors, all promoted closer co-operation between the operators. As told by a former shift manager: *“Something happened in the wet pulp control room when the new process control system was in place.”* Also in the recovery control room operators were moved closer together, enabling a better co-operation and planning of the production within their department.

The project has been criticised for implementing the changes with a staff that was unprepared for the new structure and tasks. However, the organisation was able to keep up the production from day one because the remaining employees knew which tasks that had to be done regardless of organisational structure. One employee has called this “misunderstood kindness”, meaning that most employees worked in old roles for a too long time, and thus delayed the new organisational principles being implemented and practiced.

After the “B-91”-changes, neither management nor workers were satisfied with all the parts of the process control practice. The organisation and personnel management at Tofte and the trade union both in parallel and individually planned how the tensions and challenges that the new organisation design had given best could be handled. In the next section I will discuss Toftes’ attempt to improve routines through this project.

#### 2.5.4 Employeeship as an organisational development project

Since the union and the management had common goals, a co-operation was early established in order to find a common platform. Seminars were held on the topic, and the main outcome of these seminars was that one first had to state a need and then what the form and content of the education should be. 70 employees were invited to the project start up conference in February 1995. These were managers, trade union leaders, and employee representatives. It was not regarded as an issue to change the organisational structure, but to make the actual structure function better.

In the minute from the meeting, two major factors were highlighted as issues to treat in a coming organisational development:

- **Responsibility distribution in the plant**
- **Co-operation**

These two factors are both central in process control. In the same minute of meeting the coming project leader wrote,

*“...too many tasks at once was an organisational problem at Tofte. Too many projects were run at half speed and with poor motivation. If focus is placed on delegation, the decision process and responsibility as Tofte’s organisation principle states, a distribution of workload will be a result. Today the workload is too heavy on some persons and this makes tasks that are not first aid in operations and maintenance, more difficult. A paradox is that this project will lead to yet another task. We will never get a development without use of resources on behalf of something else.”*

Further he was doubtful whether the organisation and personnel department had to be the driving force despite the attempts to ground the project as a line responsibility (IR. Thun, 1995).

During the development process, the working title was changed from “leader education for everybody” to “course in Employeeship”. A Swedish model seemed to cover most of the aspects that Tofte wanted to cover. To make the story short, contact was established and the course material was translated into Norwegian. For more details of the original Swedish model and Toftes’ modified model, I refer to Appendix 4.

A total of 19 courses were conducted from February 1996 to January 1997. 383 out of 395 employees participated at the courses. The way the courses were conducted and the content became a success (Stendal, 1997). The instructors managed to create an open and honest atmosphere and only three out of 383 were negative immediately afterwards, although many had stated their scepticism beforehand. The courses also served as a venting arena for frustrations and anger from the demanning in the “B-91” project. However, as time went by, the impression of having been at an interesting course and learnt to know some new colleagues dominated. Employeeship itself did not represent any new structures or new routines, and most employees carried on as before. I have however argued in the evaluation report (IR: Stendal, 1997) that the learning arenas, which are the main theme of this thesis (Chapter 6) can be regarded as new structures and in part as results of the Employeeship project. I regarded this as an important means by reporting from the project.

In the next section I will present Tofte's products, customers, and its strategy to handle present and future challenges. I will have an emphasis on a recent project in order to better control incoming variances before I make a summary of this chapter.

## 2.6 Demands from the market . -Tofte's products, customers and strategy

Tofte is the only plant in Norway, that produces bleached sulphate pulp<sup>20</sup>. According to Tofte's strategy (from 1996):

*“Tofte’s core business is concentrated to bleached long and short fibred pulp. Tofte will deliver bleached long and short fibred sulphate pulp of high and stable quality to paper and carton producers in Central and North Europe. Tofte will utilise its logistic prerequisite by being a producer of high quality bleached eucalyptus pulp to Western Europe.”*

Tofte has no possibilities to compete with the low cost producers of market pulp in South America and in Asia. However the plant makes efforts to reduce costs, but the main strategy is to offer special products based on long fibered pulp to the wood containing printing paper and shorter fibres to wood free printing paper and special paper<sup>21</sup>. This strategy is conducted through a project named “Tofte 400” which I will return to later in this section.

The end use of long and short fibered pulp is given in Table 2.5 (Based on sale in 1997).

**Table 2.5 End use of Tofte pulp in paper qualities (in %)**

Paper quality	Long fibres	Short fibres
Special paper	17	27
Wood containing printing paper	37	0
Wood free write- and printing paper	25	48
Cartoon surface	8	10
Soft tissue	13	15

---

<sup>20</sup> The other sulphate pulp mill in Norway is Peterson Linerboard Moss, with a yearly capacity of 250,000 tonnes unbleached kraft pulp. Tofte and Peterson Linerboard Moss are thereby not competitors.

<sup>21</sup> Wood containing paper is made mechanically and the yield is about 98 %. In wood-free paper most of the lignin is removed in order to give high paper strengths and not give rise to colour. The yield is about 50 %.

Tofte is an export-oriented plant. 65 % of the products are exported mainly to Northern Europe. Domestically Norske Skog is the biggest consumer of pulp in its newspaper and magazine paper plants.

Depending on the end use, paper plants have different quality measures. Tofte's challenge is then to adjust wood properties with production requirements in order to satisfy customer's various demands. Tofte manufactures 4 main qualities plus 22 sub qualities. Main customer demands and expectations to Tofte as a pulp supplier are:

- Level of pulp qualities
- Stability of pulp qualities (no variance between production campaigns)
- Properties suited for use (purpose)
- Delivery of correct amount to correct time
- Correct marking
- Service
- Serve customers with product knowledge
- Health and safety
- External environment.

The first 4 points in the list are very much related to control of incoming variances in the wood species. In order to meet the customer demands, Tofte needed to find means in order to get as good control of incoming variances as possible also on long fibre qualities.

It was regarded as necessary to further increase the production capacity as one measure to reduce unit costs. In 1993 a study called "Tofte 2000" was conducted. This project had a price estimate of NOK 1,600 millions, and in the uncertain market situation it was considered too expensive by the management group at Tofte. Another uncertainty was how far the customer demands would go in direction of totally chlorine-free bleaching (TCF) and making the plant totally effluent free (to sea). The TCF process would make the plant even more integrated and complex to control. The calculations from the study were however not wasted. A new conceptual study was made at Tofte based on keeping the most capital intensive equipment more or less unmodified and removing bottlenecks unit by unit in order to increase production capacity to 420,000 tonnes within year 2002, see Figure 2.1. This project was named "Tofte 400" and became the important strategic instrument in the development of Tofte. The project was organised in four main elements, very similar to the main elements in the value chain (Porter, 1985):



1. Market: Develop a market plan
2. Wood/logistics: Develop strategy for wood supply and product logistics
3. Product development: Further development of more tailor made short and long fibre pulps.
4. Technology development

All projects have a price estimate of NOK 600 millions (1997). Projects in the production were conducted stepwise. The market strategy that was completed within the six month period of 1997 was the basis for the other projects. It showed that Tofte has market potential to deliver 420,000 tonnes yearly, but that the long fibre quality had to be improved and more tailor made. This information from the market confirmed the direction of the already started product and process development.

When “Nye Tofte” was started in 1980, the main purpose was to secure a customer of wood for the farmers in Southern Norway. The farmers are best paid for timber suitable for building materials. The price difference between this and wood for the pulp and paper industry is about NOK 250,- per solid m<sup>3</sup>. The rest of the log, about 20 %, is sent to Tofte as sawmill chips. Top logs, thinnings, and logs not suitable for building materials are Tofte's Norwegian wood source.

Traditionally wood farmers have followed their natural seasonal variations with a peak in the timber harvesting during the winter season. This leads to long term storing and decay in both quality and quantity of the final pulp. This is illustrated in the following table, showing that the customers’ demands are placed at the bottom of the hierarchy:

**Table 2.6 The traditional method (Norske Skog Research)**

Wood	Specified yearly/weekly plans on quantities Delivery according to harvesting (much during winter/spring, less during summer)
Plant	Process / process adjustments Fibre quality will be what it is
Customers/quality	Big variations in fibre qualities Customer complaints

In a speech in 1990 (Storebråten, 1990), Tofte's production manager formulated the following headline: “*The sulphate plant- the wood supplier's dumping ground?*” The background for this rather provocative question is found in Table 2.6. If Tofte was to survive, it had to comply with customer demands. And if Tofte was able to meet those demands, they needed a better control of the wood supply. This can be illustrated in the following table:

**Table 2.7 The new method. Control of fibre quality (Norske Skog research)**

Customer/quality	-Specified demands to fibre/quality dependent on use (brightness, cleanness)
Plant	-Knowledge about wood and fibre quality -paper theories, paper knowledge -Transform customers demands to wood selection -Process / process adjustments
Wood supply	-delivery of correct amount wood with correct fibre quality (fibre dimensions) at correct time

In the same article, Storebråten refers a researcher from PFI from 1929: “*...one should make efforts to quality determine wood in order to sort high quality wood from low quality*”<sup>22</sup>.

Storebråten in the same article posed some self- criticism by stating that the plant perhaps got what it deserved as it was not able to pose practical demands to the wood suppliers.

In 1987 Tofte began to import eucalyptus in order to offer customers both long and short fibred pulps and to utilise production capacity, as access of Norwegian spruce and pine was limited. When the article was written in 1990, Tofte had experience both with the original method and the new method (Table 2.7).

*“When producing eucalyptus pulp the plant controls the wood supply based on knowledge about wood properties and the customer’s and their demands to the pulp. Eucalyptus wood can vary extensively, but proper laboratory pre testing and controlled purchasing and blending of species correct this, and an even quality on the final pulp is reached. Feed back from customers tells us this. This model is then to be compared with the old model where the main purpose is to consume wood”.* (Storebråten, 1990)

<sup>22</sup> The original text from Gustav Klem in ”Meddelse nr. 5, 1929:....at man foretog skridt til at faa innført en kvalitetsbedømmelse av tømmer som i store gjennomsnit kunde adskille det gode fra det daarlige”

The 1990 article also contains theories on how to sort wood and a bigger project conducted by Norske Skog research and Storebråten at Tofte (at that time head of technical development) was launched<sup>23</sup>. The sorting started in 1997 and a new chip pile that made homogenisation of various wood chips possible was built. This far the results have fit in well with the theoretical assumptions and thus strengthen Tofte's marked position.

In this section I have given an outline of Tofte's products, customers, and strategy. I have been more specific on one particular project aiming at having better control of incoming variances of spruce in order to show how the strategy aligns with customers demands. Finally I will sum up this Chapter by focusing on Tofte's remaining process control challenges.

## **2.7 Summary and further challenges**

A modern pulp mill is a large and complex process plant that places various demands on the social system. In addition to the challenges from the production systems, there are strong demands from the external environment. These are owners with demands to return on investments (i.e., pressure to reduce costs) and customers with their demands, such as stable product properties and tailor made products. The demand for lower costs was the major reason for the slimmed organisation Tofte got in 1992.

A SWOT analysis<sup>24</sup> was made at Tofte in 1997. Based on this SWOT, the top leader team at Tofte made its own SWOT and from this some selected topics regarding technology and organisation are selected:

---

<sup>23</sup> 848 logs from different geographical locations were cooked and tested in the laboratory at Tofte. It ended in a practical theory of how to sort spruce in two classes based on desired product qualities. The timber measurer measures the log diameter, and for each unit of timber he measures an average distance between the year rings. In this process, the timber measurer is not automated. Quite the contrary, he uses his eyes to pick out the typical log on which he measures the year ring distance. This information together with growth altitude above sea level, an estimated fibre length is made (empirical equation based on the tests). Based on a set fibre length value, the spruce is sorted into two piles -one called "spruce 1" with longer fibres and "spruce 2" with shorter fibres and more thin walled fibres. With thinner fibre walls, less power is needed in paper plants to transform the pulp to desired properties.

<sup>24</sup> Strength, Weakness, Opportunities, Threats. As business strategy was one of the topics at the Employeehip courses, all employees participated in a SWOT analysis. The results from each group (four at each course) were presented for the managing director before his orientation about strategy. The entire analysis is presented in the evaluation report (Stendal, 1997).

**Table 2.8 Selected points in Tofte's SWOT analysis**

Strengths:	High competence in core tasks Modern and effective production Producer of both short and long fibre pulp An organisation with a big potential
Weaknesses:	Specific quality problems, mainly related to long fibres Varying degree of Employeeship practice High costs
Opportunities:	Taylor made products Quality, product, and customer knowledge in the entire organisation Organisation and employee development Production increase at low cost Exploitation of new technology
Threats:	Loose key personnel General problems in recruitment in Norwegian process industry

At a conference prior to the Employeeship courses in 1995, Tofte's employees analysed their situation after the demanning and reorganisation in 1992 to be a need for better *responsibility distribution* and *co-operation* in the entire organisation. The project "LOOK 92", which was meant to "secure" knowledge development for the process operators, had failed, and the development in the control rooms from 1992 until 1996 had too a large degree taken place with operators learning from each other in the control rooms and also relying on their knowledge and skills prior to the demanning. Some learning possibilities were also given when the process control systems were changed. A questionnaire was completed by all employees prior to the Employeeship courses, and one of the interesting answers was clearly lack of profession development possibilities (IR: Stendal, 1997).

At Tofte there was a need to improve capacity utilisation (see Figure 7.2) and thereby produce more tonnes and at the same time reduce maintenance costs and raw materials costs. Also the production manager at Tofte repeatedly has complained of what he calls his organisations' lacking ability to learn form experiences (i.e., failures in production).

Thus many factors, both from the external system, the technical system, and the social system

at Tofte, pointed to a need for better learning systems in the production section in order to maintain and develop new knowledge related to improved production. There should also be a need to organise these efforts in order to improve the distribution of responsibility and co-operation regarding professional development and thereby production with lower costs.

How two such learning systems were developed and used at Tofte is the theme of this thesis. Before I describe and analyse the two cases, I need to present and discuss literature in relevant fields. I start by giving a brief introduction to socio-technical system thinking (which I have used in the analysis of Tofte) and how this perspective is an alternative to scientific management (Taylor, 1911). Further I will present some characteristics of a process plant. Some of these are treated in the present Tofte description, but the presentation will serve as a broader basis for better understanding challenges to learning systems in process plants. I will continue with the development of a theory of various kinds of knowledge in process plants before I discuss how such knowledge can be gained by different kinds of learning in various learning arenas.

## CHAPTER 3

### A PROCESS PLANT AS A SOCIO-TECHNICAL SYSTEM

In this chapter I will present socio-technical system thinking as one perspective of analysing a plant. I used this perspective in the analysis of Tofte without being specific on the theories. As an important part of this section I will present differences between this new paradigm and the older one based on scientific management (Taylor, 1911) as learning conditions changes depending upon how a plant is organised. I will however start this chapter with a presentation of some characteristics of a continuous process plant as these give more background to understand the need for knowledge and skills along the production line and thus how a production section should be organised in order to improve learning.

In the next chapter of this theoretical discussion I will further argue that knowledge and skills in production are becoming increasingly important and develop a theory of “process understanding”. I will discuss three main models of learning regarding the demands given by the production systems in order to develop such process understanding and introduce the term *learning arena* as a model and tool for discussing learning in a process plant. At the end of the chapter I will discuss and refine my initial research questions given in the introduction by the new insights I got based on the theory reviewed.

#### 3.1 Different modes of production

Various products require various production modes depending on the desired properties of the products. In order to better understand the concept of continuous production, which is the production mode discussed in this thesis, I will start by comparing with other modes of production. In a study reported from Woodward (1965) in England, 100 various production firms were classified into three main categories:

1. Unit and small batch production
2. Large batch and mass production
3. Continuous production (process)

Simensen (1998) made a similar classification into discrete, batch, and continuous industrial manufacturing processes. The classification depends mainly on whether the process output (products) appears in finite quantities of discrete parts as batches or in a continuous flow.

In unit production, which is a discrete process, products are classified into lots that are based on common raw materials, production requirements and production history. A group of parts (a lot) moves as a unit between work stations while each part maintains its unique identity. The product can appear as single parts such as bolts and nuts or as an aggregation of single parts into a compound product such as a car (Simensen, 1998).

Batch processes are neither continuous nor discrete, but they have characteristics from both. The product output from a batch process is denoted as a batch. As for the lot in discrete manufacturing, a batch has common raw materials and production history. However, the content in a batch will be one product, and this makes batch products somewhat like a product from a continuous process. Food, pharmaceuticals, and speciality chemicals are typical products from batch processes.

In continuous production materials are passed in a continuous flow through various equipment and unit operations from raw materials to finished products. Products can be classified as dimensional, i.e., measured by weight and/or volume. Typical products are petroleum, common acids and bases, pulp and paper, and plastics.

Batch and continuous production take place in process plants. The concept “process” is rather general and is used in many terminologies and in daily language. A definition of process as related to process industry is “*a systematic sequence of chemical, physical and/or biological activities for conversion of raw materials into products*”. (Based on Simensen, 1998:26).

Unit operations can be exemplified as reactions, separation, heat exchange, pumping, compressing, and so on. In a process plant, units of various kinds and sizes are combined in order to transform the raw materials into products. The main technologies are often combinations of physical, mechanical, thermal, and chemical processes. In addition, technologies related to construction, mechanics, automations, electricity, laboratory, and computing are present in all modern process plants. Both Simensen and Woodward argue that there is often no sharp distinction between the various production modes and combinations in

which they may occur; e.g., before continuous cooking became possible in the pulp industry, wood digestion was based on batches while the rest of the processes were continuous such as pulp washing, bleaching and drying.

Unit production was by Woodward (1965) regarded as least complicated whereas continuous production was regarded as most complicated. Woodward found the tallest and most narrow organisational pyramids in the process industry. One might propose that this was due to the tight technological couplings within a continuous process plant when production was controlled through a bureaucracy. In the following section I will describe more detailed characteristics and trends in the technological development of process plants.

### **3.2 Characteristics of a continuous process plant**

I start this section by presenting characteristics of a continuous process plant and trends in the technological development of a process plant.

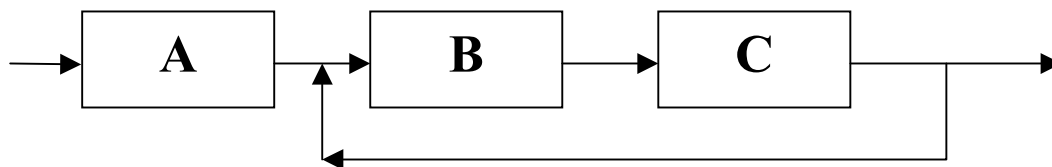
A process plant will have to operate 24 hour 7 days a week. The main economic reason is the capacity utilisation. A process plant is capital intensive both in plant investments and in variable production costs. This fact places demands on the employees for a high and stable production rate and capacity utilisation of a plant in order to reduce costs per produced unit. Another related main factor is the time and cost required for stopping and not least restarting a big, complicated integrated plant. After a complete stop of a plant, it may typically last one to two days before a new stable production level is reached. In the meantime, off grade product qualities often are produced and utilisation of raw materials and energy is not optimal.

Continuous production requires that a major part of the production personnel follow a shift cycle while the rest of the plant personnel may work daytime. This introduces challenges in relation to co-ordination and thus in information and communication between shifts in control room(s) and between the shift and the daytime staff. On average, shift personnel will meet daytime personnel only in 25 % of their ordinary working hours. This fact heavily restricts direct contact with daytime operations and maintenance staff as these traditionally work



daytime<sup>25</sup>. The interaction between “operations” and “maintenance”, is described in Appendix 5.

External pressure from customers such as demand of more tailor made products and just-in-time (JIT) deliveries, from authorities and customers on reduced effluents, from vendors who offer new or modified technical solutions and not least from owners on increased profitability, forces process plants to change. There are therefore characteristic trends in the modern process industry. One is a trend towards more physical integration in process plants. Given both cost and environmental concerns and demands, modern plants recycle mass and energy to a larger extent to economise with input resources and thus also try to minimise negative environmental impacts. This introduces even more physical coupling (feedback loops<sup>26</sup>) between units in a plant. As a result, process control is becoming more complicated as deviations from one source may propagate quickly upwards and downwards the production line. If buffer tanks are removed or storage time become shorter as a result of a higher production rate, the deviations may spread even more rapidly if not taken care of by a human and/or automatic control system. The feed back loop can be illustrated in the following figure:



**Figure 3.1 Simple sketch of a plant consisting of unit processes**

Due to high capital cost there are only seldom any redundancy of main equipment. The trend is towards fewer and bigger units within a plant. Together with a reduced buffer capacity, this demands good systems of preventive maintenance and effective repair.

---

<sup>25</sup> The still most common way of organising gives rise to these challenges. There are however choices that reduce the given problem. With integration of more maintenance functions on shifts, the above stated challenges will be reduced.

<sup>26</sup> Feedback loops are common in process control. The output value is measured (rate, temperature, pressure, etc.) and the result is transmitted, i.e., fed back to a controller which then adjusts incoming parameters in order to reach the desired output value.

Another major trend is the developments in mechanisation and not least instrumentation and computerisation in plants. Still more rapid throughput and narrowly kept product quality limits have been made possible through these improvements. As a result of this, physical interventions with the processes by process operators have become more rare, and mostly in connection with stop and start situations.

Process equipment is now remote controlled from typically one or more control rooms within a plant. The trend is towards one main control room since earlier physical / economic limitations in signal transmission from field instruments are strongly reduced. Improvements made in measurement devices enhance process control possibilities and accuracy and also enables advanced automatic control. One control centre is also feasible in order to ease overview and co-ordination. It also opens for more rotational possibilities that are not restricted to older control room boundaries and it may save manpower. Increased computerisation and instrumentation also means that most interventions with the transformation processes are now performed via a symbolic medium presented on monitors in the control room.

This far I have briefly treated some key characteristics and trends<sup>27</sup>. In the following I will give a more detailed account of process or variance control, different operational phases, and the need for representations. Finally I will sum up and list the requirements that need to be handled by the employees in a plant.

### 3.2.1 Process (variance) control

A key characteristic of process plants today is the high degree of mechanisation and instrumentation with remote control needed to keep variances in a plant under control. Parameters such as flow, temperature, pressure, concentrations of chemicals, and speed are whenever appropriate and possible measured by a combination of mechanical and electronic devices. Computerised process control technology allows for a high degree of utilisation of production equipment and raw materials, and it also keeps products within narrowly specified quality limits and saves manpower.

---

<sup>27</sup> In Appendix 6 a summary list of features and characteristics are given.

### **Four modes of process control**

A self-regulating production system requires at least the following components (Engelstad, 1970a):

1. A production unit that converts a specific input material into a specific output.
2. An output standard against which the output of the production unit can be judged at any time.
3. A measuring device that can detect deviations from the target output standard and feed the information back to a “brain” unit.
4. A “brain” unit that can translate the information received into a new set of operational instructions, appropriate to returning the production performance to the target, while also taking the momentary input characteristics into consideration.
5. An operation unit capable of carrying out the operational instructions.
6. An input standard (usually identical with the output standard of the preceding production unit) against which the input can be judged and a feed forward to the “brain” unit of information about momentary deviations.

The “brain” unit will either be a human brain in manual control or an electronic process controller. The degree of human interactions in a process plant will depend upon the degree of automation and the stability of the plant. The degree of direct human interaction with the controlling systems in a plant can be classified in four modes:

1. Manually operated devices such as hand valves.
2. Controllers and motors put in a manual mode in the control system.
3. Automated control.
4. Advanced control.

1. In a modern fully automated plant, there will still be a number of manually operated valves. Most of these are not used during normal production, but they are necessary during start and stop of the plant or in case of necessary maintenance during production.

2. Most process control systems will have a possibility to be put in a manual mode. The controllers will then be operated from the control room, but the operators decide set point positions, and these will be fixed until the operator decide to make new changes. This mode

of operation requires special attendance from the operators as they must judge the total situation often with many controllers in a manual mode (as in start- and stop situations). The process operator will decide when the control circuit can be turned into the automatic mode.

3. In an automated control mode, preferred values (set point) are set by the operators, e.g. tank level, a desired temperature or pressure, and speed of a conveyor belt, and the automated system will try to keep the parameters at the set points. A control circuit may consist of a single loop or more loops may be connected where the output signal from one controller may give a set point for another controller. This is termed cascade control.

4. The fourth level is a more advanced control. Here several control circuits may be programmed in sequences to keep the production rate in a steady state or make all necessary changes in set points automatically if, e.g., the production rate is changed. Benefits with advanced control is that production experience is built into the systems and necessary set point changes are made to minimise fluctuations which may otherwise arise. At a continuous pulp mill a typical programme makes it possible to select production rate through the digester and the programme will take care of the remaining set point changes covered by the system. With advanced control, deviations in practice between different operators and shifts are reduced. However, the operator in charge will at any time have the possibility to change the automation mode. He/she must also decide when the conditions for the process to be put in an advanced mode are present and when the process has to be operated in an automatic or manual mode. An example here is when operations are unstable and some controllers are outside their normal working range.

### 3.2.2 Different operational phases

The operation of a plant tends to fall into different more or less distinct phases with different task requirements to the production staff:

1. Stable operations
2. Unstable operations
3. Shut down / start up
4. Emergency

The distinction made between stable and unstable operations is however in some cases most troublesome since in practical operation there is no sharp distinction between what is regarded as stable and what is regarded as unstable. Perby (1995) makes a point out of this when she argues that no such limit exists. However, different requirements on the operating staff are present depending upon the degree of instability.

Stable operation is the desired goal in a continuous plant. It follows the homeostatic principle of steady state in dynamic systems. When variances are controlled within specified limits, attempts can be made to optimise with regard to production rate, quality, environment and cost and thus challenge steady-state conditions but without violating them. When process control systems keep the process in a steady state, the operators' main task in the control room will be monitoring. However, steady state conditions will often be violated due to variances from another section not controlled at its source, or from some malfunctioning equipment in own section that will influence the production and thus has to be taken care of. This mode requires active involvement in analysing the problem and a decision on how to solve the problem(s) in order to bring the processes back to steady state conditions. Also variations in raw materials may impose unstable conditions and need to be taken care of. Scaling or growing in various equipment as well as wear and tear may also lead to situations that can easily lead to an unstable condition if not taken care of in time. Unintended stops have to be avoided, as consequences rapidly will propagate upwards and downwards the production line that may cause reduced speed and finally a complete stop.

Unstable operations will typically be imposed by equipment failures or on some occasions faulty operations that will lead to a stop and start situation. Depending on the duration and extension of the stop, special precautions have to be taken in order to be able to start the processes again properly. (E.g., if chemicals are cooled in pipes, they may stiffen or crystallise if the pipeline is not properly drained). A common experience is that new problems arise during start up. This may be caused by an improper stop operation or that equipment is started too quickly, not allowing for thermal expansions to take place. A process control goal is thus to avoid start and stop situations. Due to the shift cycles, it may be years or at least several months between each time an operator will have a chance to practice a stop or a restart situation. Stop and start therefore calls for extra awareness from the production personnel in charge.

### Shut down

One special situation is a shut down phase where a major overhaul will take place<sup>28</sup>. This will typically involve the whole plant. The duration will depend upon the amount and type of work to be done. When a plant to a large extent is integrated, much effort in stop planning has to be made in order to be able to inspect and maintain and not least secure a safe and smooth start up.

During a shut down all systems in a plant will be made pressure-less and cold. The process operators may be engaged in different cleaning activities and also inspection and maintenance work. If new equipment is to be installed or if modifications are made, operators are typically also involved in testing. A shut down phase gives the production personnel a rare opportunity to look inside different equipment to see the details of the constructions and how operation has affected the equipment over a longer period (growing, scaling, corrosion, and so on). It may also provide explanations for various production problems, as mechanical failures within process equipment will be uncovered.

Emergency situations may include fires, leakage of hot or toxic gases or liquids and explosions. A process plant often implies high pressures, large volumes, and high temperatures. It thus requires a high technical standard on equipment and safety systems. The staff has to be trained in the different emergency situations that may arise within their department and how to behave in different situations. In most plants, certain task forces on each shift train on a regular basis to cope with different situations in potential emergency situations. Emergency situations are avoided by having a high technical standard, well designed safety systems and good operational practices.

### 3.2.3 Representations of production equipment and systems

In order to operate a plant safely and optimally, develop and maintain it, different kinds of representations are required due to the amounts of and complexities of the production equipment. A representation may be regarded as a simplification of the real plant and will

---

<sup>28</sup> In the pulp industry, one yearly stop is typical. Clean up, inspections, maintenance, and equipment modifications are typical tasks. Improved technologies and operational practices tend to increase the periods between major overhauls. E.g., at Shell's refinery at Sola, Norway, the period between major overhaul has been increased from 1 to 4 during the last years.

vary depending on its purpose. The most common representation is a process flow sheet. This will show the different process equipment, how they are connected, and the control loops. While reality is three-dimensional, still the most common representation is two-dimensional and will also in this respect differ considerably from reality. Other representations are piping and instrumentation diagrams (P&IDs or flow sheets) showing the placement and functionality of instruments and interlock diagrams which are schemes showing the logic behind programmed safety precautions.

Modern information technology allows processes and parts of them to be represented graphically on monitors in control rooms. Thus this technology is highly flexible and can be used to inform as well as automate (Zuboff, 1988). However, the degree of details has to be less on graphical monitors than on P&IDs.

### **3.3 Summary and implications**

In this section I have given some characteristics of a typical process plant. Technological developments, not least within instrumentation and computerisation, in addition to other external demands, forces process plants to change in order to stay competitive.

The most striking characteristics of the process industry are:

- One single production line because redundant (not utilised) equipment cost too much.
- Higher degree of equipment utilisation as production speed will increase.
- In order to economise with resources, plants are becoming physically more integrated and thus more complex to operate.
- Automations tend to increase the technological complexity but enhance the process control.
- Disturbances will rapidly propagate up and down the production line(s) if not controlled<sup>29</sup>.

---

<sup>29</sup> In Appendix 6 more features and characteristics are listed.

The trends and characteristics discussed in this part have major implications for the employees in a plant. As there is a strong tendency in the industry to reduce costs by reducing manning, those who are left will accordingly get more responsibility for the production result.

Given the characteristics discussed in this section, there is thus a need to take rapid qualified decisions regarding corrective actions. This requires a highly qualified work force, and place demands on the employees' knowledge and skills and not least their abilities to learn. The way a plant is organised is of major importance for the learning possibilities. As my focus is learning about process control, I will therefore discuss more closely how a "new" form of organising tasks better meet the challenges given by technology and external conditions and contrast this "new" form with that traditionally found in process plants. This was what Woodward (1965) found as a tall and narrow organisational pyramid.

Given the characteristics of a continuous process plant, in addition to demands and needs from the external system, is it possible to incorporate these in the social system and at the same time provide good jobs?

*"Levels of variety, autonomy, feedback, task completeness, task significance, interdependence with others, and required skills are all affected, if not predetermined by the nature of the technology in use," (Pasmore, 1988:58).*

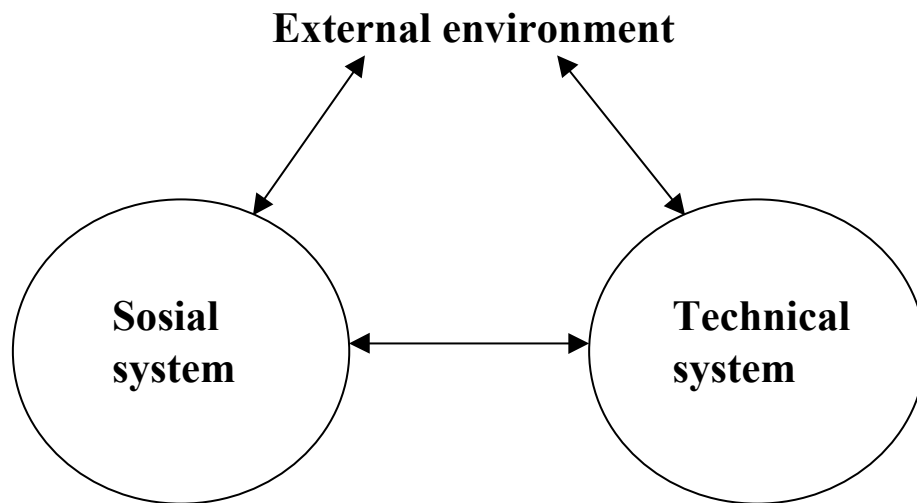
How a plant is organised and managed in order to best control variances is of major importance in the socio-technical paradigm that will be discussed in the next section.

### **3.4 Main aspects and development of socio-technical systems**

The organisational theoretical direction that has focused most on incorporating technology and technological choices, is the socio technical system thinking (STS). Pasmore (1988:1) states: *"Every organisation is a socio-technical system, but not every organisation is designed using the principles and techniques that have become a part of the STS approach."* The socio-technical model is based on the assumption that technical and social systems are linked as shown in Figure 3.2 and that these two systems have to be jointly optimised in order to let the organisation function optimally. (Levin et al., 1994). The socio-technical thinking



delivers knowledge both on how to design work in process plants and how to go about using participative approaches to the organisational change process.



**Figure 3.2 The enterprise as an open socio-technical system**

The STS perspective considers every organisation to be made up of people (the social system), using tools, techniques, and knowledge (the technical system) to produce goods or services valued by customers (who are part of the organisations external environment). The social and technical systems follow different laws and processes. While the social system is ruled by laws of motivation, learning, and so on, the technical system is ruled by the laws of the natural sciences (Emery & Thorsrud, 1976, Pasmore, 1988). In the technical system, interdependencies among elements are fixed and fully explicable with reference to universal valid laws; the interdependencies between for example pressure, viscosity, and temperature explain how liquids flow through channels.

In a process plant the technical system will typically consist of artefacts such as tanks, pipelines, pumps, reactors, heat exchangers, valves, measurement devices, controllers, and so on. In addition there are information systems, which communicate electronically with measurement devices, controllers, and motors. The electronically given information is also a basis for written shift reports. Methods, configurations, procedures, and knowledge are also part of the technical system. This point is also made in Nonaka & Takeuchi (1995) as they argue: “*Technology at a higher aggregate is about knowledge*”.

How well the social and technical system are designed with respect to one another and with respect to the external environment, determines to a large extent how effective the organisation will be. In the STS perspective, the way to enhance quality of work life is to change what people actually do at work, and in ways that make them more productive, more able to use their knowledge and skills, more able to co-operate with others in solving interdependent problems, more able to expand their capabilities, more autonomous in their control, more in charge of the technology they operate and more secure about their future (Pasmore, 1988:151).

### **An organisation as an open system.**

Emery & Trist (1963) recognised that organisations must be regarded as open systems, borrowing from Bertalanffy's (1950) development of general systems theory from biology. The open systems perspective holds that every living organism depends upon exchange with its environment for inputs which allow it to survive. The socio-technical system perspective insists that whatever decisions are made about organisational design should meet the demands of the external environment as well as the internal social and technical systems (confer Figure 3.2). Internal measures of success are viewed as insufficient predictors of organisational survival; the external environment is the ultimate judge of design effectiveness. If consumers of pulp, providers of capital, or providers of labour withdraw their support, no amount of improvement by internal standards will prevent catastrophe (Emery & Trist, 1963). Improving the technology of an organisation without improving human capabilities to operate the technology or the market's ability to absorb the increased output, is a waste of resources. Social, technical, and external environmental sub-systems are richly interconnected, and organisational effectiveness depends more in their harmonious interrelationship than upon their individual optimisation.

In the next sections I will discuss the implications on variance control by regarding a plant as an open socio-technical system. In addition I will discuss the *Industrial Democracy Programme (IDP)* (Emery & Thorsrud, 1970, 1976) that took place in Norway in the sixties and how the experiences from these industrial experiments were central in learning about process control.

### 3.5 Historical development of STS

The STS paradigm has evolved from site experiences in the British coal industry in the 1940s and 50s, pre-planned experiments (among these the Norwegian Industrial Democracy Programme (Emery & Thorsrud, 1970, 1976)), contemporary theories of system dynamics, and group and motivation theories.

In an initial study of the British coal mining industry, Trist & Bamforth (1951) concluded that the behaviour of organisational members were so tightly coupled to the way work was designed because technology decided the job characteristics, that the human system could not be understood without also understanding the technical system<sup>30</sup>. Emery and Trist (1965) further concluded that *changing* the design of the technical system would affect the social system and vice versa. The Tavistock studies during the 1950s have shown that it is absolutely necessary to take into consideration the organisation's technological aspects along with the human aspects if the organisation is to be economically viable and at the same time give its members adequate opportunities for involvement, personal growth, and development.

The Socio-technical system design (STSD) meant a radical departure from the Scientific Management model, clearly ushering in a new era of organisation design that is based on participative democracy. Socio-technical systems design is an applied science, which is aimed at improving the quality of work and organisation through adaptation or fundamental redesign of contents and composition of technology and human tasks. STSD can be concisely characterised as a reaction to the unilateral emphasis placed on either the technical or the social aspects of the organisation in previous paradigms (Scientific Management: Taylor,

---

<sup>30</sup> What has emerged as a new work paradigm – socio-technical systems, arose in conjunction with the first of several field projects undertaken by the Tavistock Institute in London in British coal mining industry. For several decades, the prevailing direction in industry had been to increase bureaucratisation with each increase in scale and level of mechanisation. In a newly nationalised industry after World War 2, production failed to increase in steps with increases in mechanisation. The national coal board invited The Tavistock Institute to make comparative studies between a high productive, high morale mine and a low productive low morale mine. This could at first not be accomplished due to resistance in the local mine management. Ken Bamforth, who had a background as miner and at that time was a research fellow, was asked to make a report on new perceptions he might have from his earlier industry. (Trist & Bamforth, 1951). The so called "long wall" mechanised method of coal mining followed Tayloristic work principles and earlier autonomous work teams were broken down to one man one task principles. In the Highmoore mine it was possible to mine after the old shortwall method due to improved roof control. In this mine they had evolved a form of work organisation based on practices common in unmechanised days when small work groups, who took responsibility for whole cycles, had worked autonomously. The Highmoor innovation showed that there was an alternative to the organisational model that fused Weber's description of bureaucracy with Frederick Taylor's concept of scientific management.

1911; Bureaucratic: Weber, 1947; Human Relations: Mayo, 1933). In the new perspective both factors are integrated as being components of one single socio-technical entity (Van Eijnatten, 1993:9).

Norway played an important role in the development of STS. Members of the Tavistock Institute in London, England, found it politically and practically very difficult to follow up the interesting results from the coal mining studies as the relationship between employers and trade unions in Great Britain was such that it did not allow for experimentation of industrial work. At the same time a Norwegian scholar, Einar Thorsrud, made a link with the Tavistock, and this link eventually led to real-life experimentation in industrial democracy in Norway.<sup>31</sup> The major strategy was to begin several experiments at the same time, all focusing on improving democracy at the shop floor level. This period has later on been classified as the “classical period” of STS development.<sup>32</sup>

The summaries and theoretical strategies and experiences from the four studies are reported in Emery and Thorsrud, 1970 and 1976. They stated that the Industrial Democracy Programme first and foremost aimed at the development and testing of alternative organisational forms and their impacts upon employee participation at different levels in companies. Major emphasis was placed on the concrete conditions for personal participation, including technological factors structuring the tasks, the work roles, and the wider organisational environment of workers.

Two major conceptual schemes emerged through the IDP work:

1. Socio-technical thinking that creates direct links between technology and work organisation.

---

<sup>31</sup> The Industrial Democracy Programme in Norway lasted from 1962 to 1967. It was organised in two phases, A and B. Phase A lasted from 1962 to 64 and concentrated on the experiences gained with formal systems of employee participation at board level through representative arrangements (Emery and Thorsrud, 1964). Phase B consisted of action research projects in four Norwegian enterprises. These were Christiania Spigerverk, in its wire drawing mill, Hunsfos pulp and paper mill in the chemical pulp mill department, NOBØ in the metal fabrication industry and Norsk Hydro, old and new fertiliser plant. As action research projects, they led to actual changes in the experimental departments and plants and were a basis for developing theories and concepts from the experiences in the projects.

<sup>32</sup> For a comprehensive study of the socio-technical history and development, I refer to Trist (1981) and van Eijnatten, (1993).

2. The design of work roles was done according to a set of so called psychological job demands.

According to Emery and Thorsrud (1970:19) the psychological job demands<sup>33</sup> are:

- The need for the contents of the job to be reasonably demanding (challenging) in terms other than sheer endurance and yet providing some variety (not necessarily novelty).
- The need for being able to learn on the job and continue learning (which imply known and appropriate standards, and knowledge of results). Again it is a question of neither too much nor too little.
- The need for some area of decision-making that the individual can call his own.
- The need for some minimum degree of helpfulness and recognition in the workplace.
- The need to be able to relate what he does and what he produces to his social life.
- The need to feel that the job leads to some desirable future.

These were regarded as essential to the individual worker's motivation and well being. These were also among the design criteria in the IDP project where the major design question was: How to organise in such a manner that these psychological requirements are met? Thus the researchers found that the psychological job requirements better could be met in an organisation built on semi-autonomous groups at the lowest levels of the organisation.

There seems to be little doubt that socio-technical thinking has had a major effect on organising industrial work. Socio-technical design has involved efforts to break away from Tayloristic modes of organising work and has been important in pinpointing the interrelationship between technology and social life (Greenwood & Levin, 1998) and for how shop floor workers can learn to better control variances. In the next section I will discuss more in detail how better variance control can be achieved in a process plant.

---

<sup>33</sup> These requirements soon became a part of Norwegian legislation. Thus the right to learn in work is in fact legally manifested in Norway.

### 3.6 Organising for variance control

Van Beinum (1988) has compared and discussed key characteristics of the old and new work paradigm and implications on process control.<sup>34</sup>

**Table 3.1 A comparison of old and new paradigm of work (van Beinum, 1988)**

Characteristics of the old paradigm (Scientific management)	Characteristics of the new paradigm (Socio-technical design)
Redundancy of parts	Redundancy of functions
Emphasis on external co-ordination and control	Emphasis on internal co-ordination and control
Fragmented socio-technical system, man as an expendable spare part	Joint optimisation of socio-technical system
Technological imperative – man as extension of machine, a commodity	Man is complementary to the machine and a resource to be developed
Organisation design based on total specification	Organisation design based on minimum critical specification
Maximum task breakdown, simple narrow skills	Optimum task grouping, multiple broad skills
Building block is one person – one task	Building block is self-managing group
Alienation	Involvement and commitment

There are only two basic design principles for adaptive systems (van Beinum, 1988). The choice is with regard to the way an organisation designs redundancy into its system. Unless an organisation has a certain amount of over-capacity, or redundancy, it does not have the flexibility, it cannot generate the variety, and it does not have the ability to self-organise, all of which are necessary to enable it to adapt to its environment. Organisations need redundancy in order to survive. The choice between redundancy of parts or redundancy of functions represents a choice between two quite different value systems. (van Beinum, 1988).

In the first option people have narrowly specialised individual tasks and are being used as uni-functional components, as replaceable parts of a machine. The basic building block is formed by the one person – one task structure. Working from this design principle, special parts have to be added to the system for the purpose of control, and to back up and replace parts whenever they fail. It creates a typical bureaucracy, that is, a rigid, highly stratified, multi-level, and hierarchical system. It reveals a mechanistic view of organisation.

<sup>34</sup> More aspects regarding variance control are given in Appendix 7.

The second option, redundancy of functions, recognises the multiple capabilities of people and gives people more complex roles. Instead of spare parts added to the system, additional functions are developed in each of the operating parts (i.e., people). Each person is thus able to perform a range of functions. People have the opportunity to be actively involved in the affairs of the workplace and to develop their ability to handle a wide range of responsibilities. Developing a worker's capacity to handle a wide range of tasks, increases variety for both the organisation and the individual workers, and creates the conditions for self-regulation. The building block in this type of organisation is the self-managing (or semi-autonomous) group (see Figure 3.3).

The concept of total specification versus minimum critical specification originates from Herbst (1976). The principle suggests that managers and organisational designers should primarily adopt a facilitating or orchestrating role, creating conditions that enables a system to find its own form. By introducing as few constraints as possible in modes of operating tools and machines or in organisational structures, more freedom can be given to the workers to design their own working conditions. Thus a higher degree of participative control can be achieved at the shop-floor level by having self-managed teams. A socio-technical theory of the efficacy of autonomous groups is based on the cybernetic concept of self-regulation. The more key variances can be controlled by the group, the better the results and the higher the member satisfaction (Morgan, 1986). Over a large array of situations, the range of variables controllable by a group is greater than that controllable by individuals separately linked to an external supervisor. The contrast is total critical specification where workers have detailed specifications on how to perform any given task. This of course requires tight managerial control. The principles discussed above can be illustrated as in figure 3.4 next page. (Emery & Thorsrud, 1976; van Beinum, 1988)

The figure to the left represents a traditional model. When a deviation or failure is detected by a shop floor worker, communications follow "the line" up to the supervisor. This will in most cases take time and before a decision can be made and communicated, the deviations from the failure will have had time to propagate and may have caused production losses. In this case the supervisor is the one who learns, as he is responsible for problem solving. He will also typically be interrupted whenever a problem occurs and become a short-term trouble shooter.

The figure to the right is a model with a semi-autonomous group along the production line. The group should have enough resources to detect the failure, analyse the causes, and decide what actions to take and implement the solution instantly. The consequences of the decisions should be fed back to the group members as early as possible in order to learn. In this model the shop floor workers are more responsible for problem solving and thus, if proper feedback is provided, they will be the ones to learn. A work group offers scope for a range of abilities and preferences. There is more room for individual differences in a work group than in standardised, individual workstations (Trist, 1981).

### The shift from an old to a new form of work organization

Organization structure according to old paradigm

Organization structure according to new paradigm

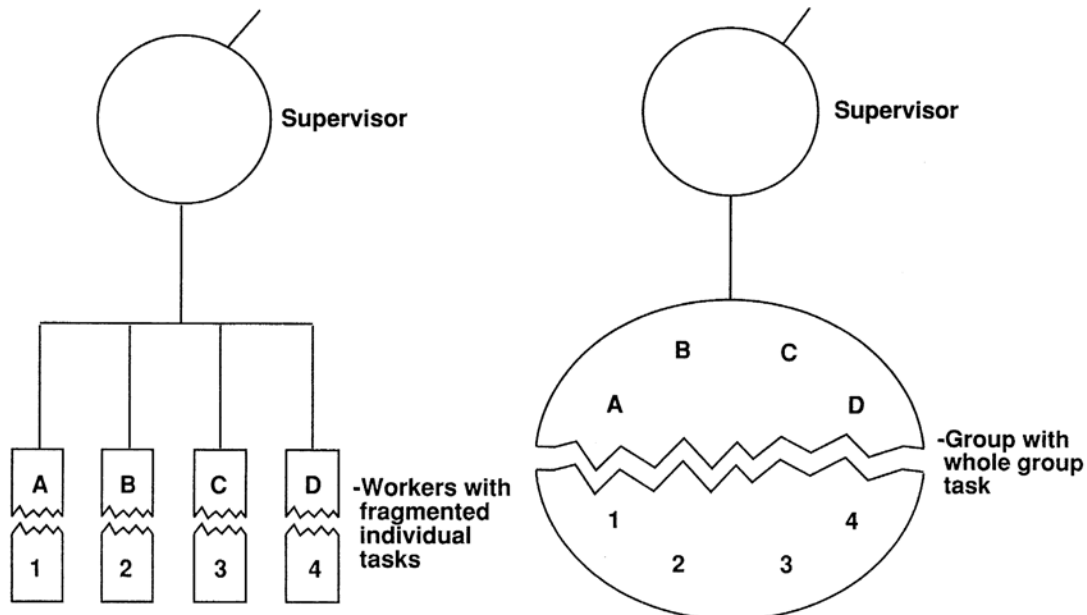


Figure 3.3 A comparison between two organisational models

#### Changes in supervisor tasks

Trist (1981) states that a change from the old to the new paradigm of work implies big changes in managerial practice. The most important shift and in practice the most difficult is the shift from external control to allow for internal control and then use the released time to control boundary conditions and seek to develop the human resources.



Use of autonomous or partly autonomous groups means a delegation of authority and responsibility down to the group level. Or to follow Morgan (1986:108):

*“Any move away from bureaucracy toward self-organisation has major implications for the distribution of power and control within an organisation, since the increase in autonomy granted to self-organising units undermines the ability of those with ultimate power to keep a firm hand on day-to-day activities and developments”.*

Based on the IDP in the 1960s, Emery & Thorsrud (1976) raised the question of levels in an organisation. Regarding the steepness or flatness of the organisational “pyramid”, this will depend on the time perspective contained in the decision making process they state.

*“A certain stratification seems necessary in order to give the management group the tranquillity necessary for them to concentrate on studying and adjusting the long term trend. But internal communication seems to be best served by an organisation so “flat” that the whole idea of an organisation pyramid can perhaps lose its overall significance.”*

Information technology and new possibilities to share information within an organisation have made the theories from the 70s even more relevant. Zuboff (1988:396-97) argues:

*“As the intellectual skill base becomes the organisation’s most precious resource, managerial roles must function to enhance its quality”. She continues: “The crucial importance of the intellectual skill base requires that a significant level of organisational resources be devoted to its expansion and refinement. This means that some organisational members will be involved in both higher-order analysis and conceptualisation, as well as in promoting learning and skill development among those with operational responsibility. Their aim is to expand the knowledge base and to improve the effectiveness, with which data is assimilated, interpreted, and responded to. They have a central role in creating an organisational environment that invites learning and in supporting those in other managerial domains to develop their talents as educators and as learners.”*

Management practice within the socio-technical work paradigm should thus be boundary control at different levels and also that of facilitators of learning. Zuboff (1988:391) argues:

*“Managers who must prove and defend their own legitimacy do not easily share knowledge or engage in inquiry. Workers who feel the requirements of subordination are not enthusiastic learners. New roles cannot emerge without structures to support them. A new division of learning requires another vocabulary – one of colleges and colearners, of exploration, experimentation and innovation.”*

Managers should be more aware of utilising learning possibilities within a plant. Morgan (1986) states that “...*although you cannot manage a human resource, you can indeed shape environments that mobilize human resources.*” Learning is a new way of working and it is a managerial responsibility to enable for learning arenas to be created and to be supported along the entire learning circle. Managerial practice should be that of facilitating for learning.

To sum up this section, a process plant has certain characteristics that can be regarded as demands from the technical system. When at the same time taking into consideration the demands from the social system, a multifunctional team (or teams) close to the production line is an unavoidable choice in order to gain and improve (by learning) variance control.

### **3.7 STS summary**

Knowledge and skills in a process plant can necessarily not be developed outside an organisational context. I have therefore included a socio-technical system design in my discussion of learning about process control. Based on characteristics of a continuous process plant (the technical system), demands from the external environment and the needs in the social system, a framework for how work tasks can be organised is provided. Although major changes have been made not least in automated process control, possibilities in being informed about all measured parameters and in the general higher educational level at the shop floor, the problems identified in the mid sixties in Norway as a background for the Industrial Democracy Programme, are still valid today. Trist (1981:42) states that the displacement from the old to the new paradigm will come about because the new form has the flexibility and the resilience to cope with turbulent environment fields, whereas the old form lacks these capabilities. For technological reasons, and external demands where cost reductions are major factors, the new paradigm is still becoming more relevant in modern continuous process industries, and many organisations have begun to include at least parts of the new paradigm into organisational practice.

The socio-technical paradigm is based on redundancy of functions which integrates the democratisation of work life and the economic performance of the organisation (van Beinum, 1988). Redundancy of functions requires multiskilled persons within a group. Thus, in the new paradigm, knowledge and learning capacity at the shop-floor are important requirements. STS provides frames and direction for learning to take place within groups along the production line. It is however not the scope of the STS paradigm to provide theories of what constitutes knowledge in operations of a plant. And the STS theories are not developed in order to cover more specific models for how learning within and across semi-autonomous units and organisational levels may take place. I will return to this issue in my analysis of the learning arenas at Tofte.

In the next chapter I will therefore discuss theories of what constitute knowledge and skills in operations given the characteristics of a continuous process plant and sum up with a definition of “process understanding”. Further I will examine how such process understanding may be developed by combining theories from learning literature with a frame for how to organise for such learning. Finally, I end the discussion with a refinement of my research questions.

## CHAPTER 4

### LEARNING SYSTEMS IN PROCESS PLANTS

Given the characteristics of a complex continuous process plant, I have argued that knowledge and skills must be provided at operators' level along the production line. A demand for redundancy of functions place even higher demands on the operators' knowledge and skills, their abilities to learn, and how learning should be organised within a plant in order to be efficient. Learning and organising for learning will be the topic of this chapter. However, according to Kolb (1984), "*....to understand learning, we must understand the nature of knowledge, and vice versa*". In order to discuss learning about process control, I will therefore first discuss knowledge in operations and sum up with a definition of "process understanding". I will continue with how such process understanding can be developed with discussing different types of learning, conceptualise learning arenas, and finally discuss how different types of learning are related to different types of arenas. The discussion will lead to a refinement of my research questions.

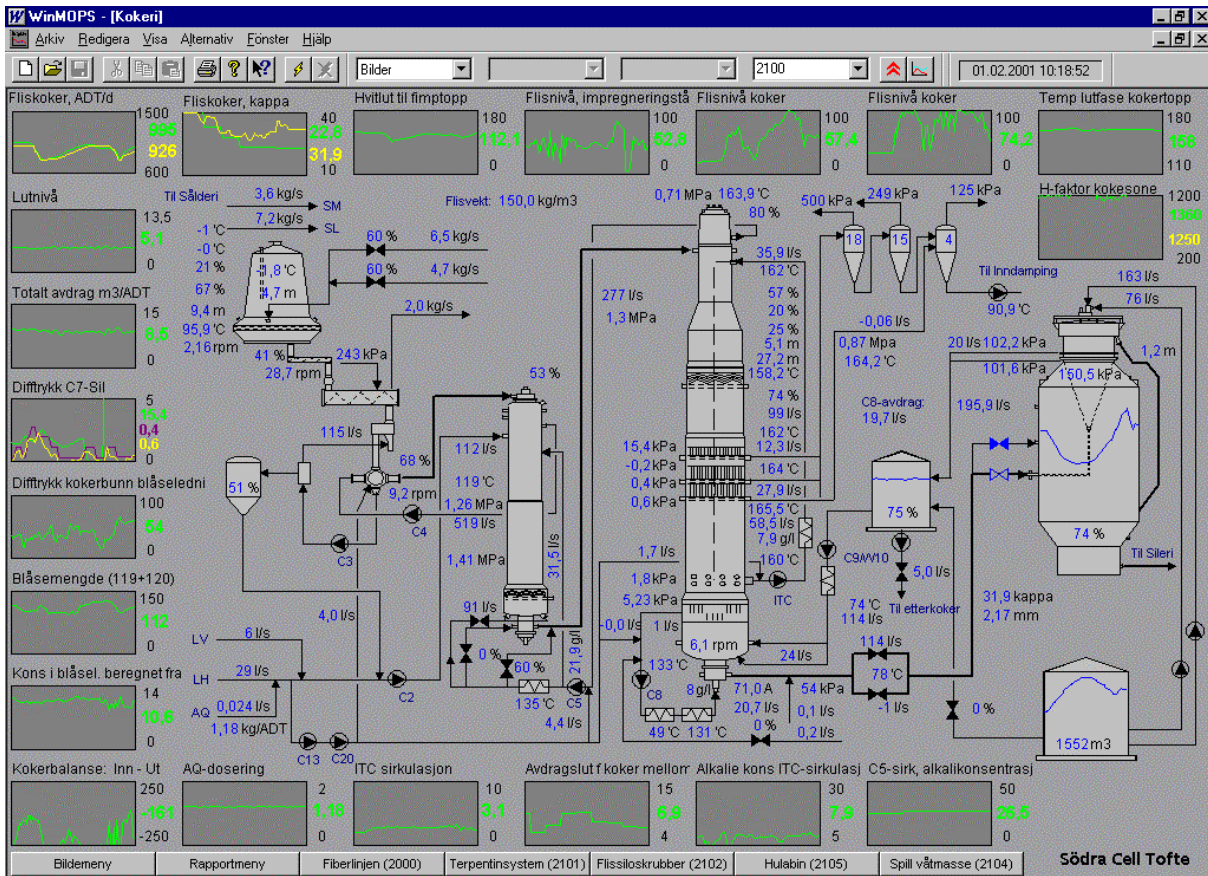
#### 4.1 Categories of knowledge in operations

Together with various demands from the external environment, there is an increasing demand to the organisation member's knowledge and skills, and also how to develop these. New technology imposes new demands on those controlling a plant. Ellström (1996) states it is not the technology in itself that is detriment for possibilities of reaching more effective production, but the possibilities it creates and how these are utilised. The focus in this section will therefore be the various kinds of knowledge and skills a process operator should have and further develop in order to utilise the various production equipment. I will start this outline by discussing the words "data", "information", and "knowledge".

##### 4.1.1 Links between data, information and knowledge

Knowledge in operations is not a clear-cut concept and can be explained in many ways. By some authors data, information, and knowledge are also used interchangeably. In a process plant, raw data from sensors (measurement devices) are produced more or less continuously.

In addition there are raw data from the process laboratory. These raw data can be made available on screens as point information, as trends or as reports. Figure 4.1 illustrates my arguments. (Text in Norwegian, MOPS<sup>35</sup>-see footnote)



**Figure 4.1 A MOPS representation of a continuous digester with side systems**

Bohn (1994) makes a distinction between data, information, and knowledge. He defines data as what come direct from sensors, reporting on the measured level on some variable.

Information is data that have been organised or given structure- that is placed in context- and thus endowed with meaning. Information tells the current or past status of some part of the production system. Knowledge goes further; it allows for making predictions, causal associations, or prescriptive decisions about what to do.

The representation in Figure 4.1 consists of data gathered from field measurement devices. The data give valve positions, temperature, pressure, tank levels, rates, and properties. All these data represent information to the user in the plant who chooses to study this

<sup>35</sup> Millwide information and Optimization System. This is a pure information system that retrieves the same measurement signals as the process control system.

representation. Information is also presented as trend curves to show development over a chosen time period<sup>36</sup>. Thus information is endowed with meaning (this particular presentation of several data sources with the past and present situation at the digester). What should be evident is that different kinds of knowledge are necessary in order to make sense of the given information and to use it actively in order to control a plant. It should also be noted that the given representation is a strong simplification of the real digester complex. Nonaka & Takeuchi (1995:59) support the distinction between information and knowledge:

*“Thus information is a flow of messages, while knowledge is created by that very flow of information, anchored in the beliefs and commitment of its holder. This understanding emphasizes that knowledge is essentially related to human action. Finally both information and knowledge is context specific and relational in that they depend on the situation and are created dynamically in social interaction among people.”*

They further state that *“Western observers take for granted a view of the organisation as a machine for “information processing”. This position is deeply ingrained in the traditions of Western management, from Frederic Taylor to Herbert Simon. And it is a view of knowledge as necessarily “explicit”-something formal and systematic. Explicit knowledge can be expressed in words and numbers and easily communicated and shared in the form of hard data, scientific formula, codified procedures, or universal principles. Thus knowledge is viewed synonymously with a computer code, a chemical formula, or a set of general rules.”* (p. 8)

They use Toffler (1990) to exemplify their view as he uses data, information, and knowledge interchangeably throughout his book “to avoid tedious repetition”.

I have argued that data and information do not have the same meaning as knowledge. Thus by having posed Nonaka & Takeuchi’s critique of general Western thinking of knowledge as something rational and explicit, I have also indicated that knowledge can be further sub-categorised. In the next section I will discuss approaches to knowledge in a process plant.

---

<sup>36</sup> This periode can be varied freely and 4 trends can be compared independently.

#### 4.1.2 Different views of knowledge

On a general basis Göranson (1988) has identified three categories of knowledge that can be applied in a process plant:

1. Propositional or theoretical knowledge
2. Skills or practical knowledge and
3. Knowledge of familiarity

*Propositional knowledge* is that part of a professional tradition that has been expressed in general traditions, theories, methods, and regulations and that we can assimilate from a theoretical study of an activity. By virtue of the fact that it can be formulated in language, it is, by contrast to the knowledge of familiarity and practical knowledge, explicit. *Practical knowledge* contains experiences obtained from having being active in a practice, whereas *knowledge of familiarity* is knowledge that can be acquired from learning a practice by examining the examples of tradition in work. Propositional knowledge, practical knowledge, and the knowledge of familiarity are interdependent, according to Gullers (1988).

Josefson in Göranson and Josefson, eds. (1988:) exemplifies the three kinds of knowledge in nursing practice:

*“Work in the medical care sector is full of unexpected complications. To deal with the degree of complexity nurses must have the ability to make a reasonable interpretation of events not covered by the descriptions in the rulebook. This requires multi-faceted practical experience, through which the information acquired through formal training can be developed into knowledge. That knowledge is built up from a long series of examples, which give different perspectives of an illness. Different kinds of knowledge are acquired, some of which can be described in generally applicable rules. This is an example of propositional knowledge. The knowledge that becomes apparent in encounters with unforeseen situations in everyday care cannot be described in a meaningful way in general rules because its core is to act with good judgement in unique situations. Propositional knowledge and the knowledge of familiarity presuppose each other and affect each other; they require many sided, practical experience in order to develop.”*

This example is a clear parallel to what operators in a process plant experience. They gain some propositional knowledge through formal courses, but these courses can not cover the local knowledge needed to master all situations that have to be mastered. Process understanding is a result of the three different kinds of knowledge: propositional, practical, and that of familiarity. The three kinds of knowledge have to inform each other. In order to make sense of e.g. the digester system representation in Figure 4.1, one needs system knowledge and knowledge of what the different numbers should be and mean to the process and product. But one must know why the numbers appear as they do. Why are the set points given as they are? How big deviations should one allow before any corrective measure should be taken? All these questions cannot be answered by means of theoretical knowledge only. Engaged operators develop a sense of what should be regarded as important to follow up over a long time. Ullmark (1996:20) states that:

*“Man has learnt to recognise even those deviations that cannot be explained through causal inferences. One has also trained and found effective ways to interfere processes. This, often denoted as tacit knowledge that is hard to collect and systemise, one cannot be without.”*

Nonaka and Takeuchi (1995) also emphasise the role of tacit knowledge and how it can be shared in an organisation in order to create new knowledge. They argue that Japanese companies have a different understanding of knowledge than Western companies. They recognise that the knowledge expressed in words and numbers only represent the tip of the iceberg. They view knowledge as being primarily “tacit” –something that is difficult to detect and express.

*“Tacit knowledge is highly personal and hard to formalise, making it difficult to communicate or to share with others. Subjective insights, intuitions, and hunches fall into this category of knowledge. Furthermore, tacit knowledge is deeply rooted in an individual’s action and experience, as well as in ideals, values, or emotions he or she embraces. To be more precise, tacit knowledge can be segmented into two dimensions. The first is the technical dimension, which encompasses the kind of informal and hard to pin down skills or crafts captured in the term “know-how”. A master craftsman, for example, develops a wealth of expertise “at his fingertips” after years of experience. But he is often unable to articulate the scientific or technical principles behind what he knows. At the same time, tacit knowledge consists of schemata, mental models, beliefs, and perceptions so ingrained that we take them for granted.*



*The cognitive dimension of tacit knowledge reflects our image of reality (what is) and our vision of the future (what ought to be).”(p.8)*

The technical dimension of tacit knowledge in the operation of a process plant is treated by Perby (1995:186):

*“In an automated plant, the operators state that they regard the computers and monitors as a working tool. As one learns to master the tools better and better, the tools to the operators as to craft men become more a sensible part of the body, as a prolongation of arm, hand, finger. The operator’s aesthetical view and feeling when he operates the plant is similar to the aesthetical judgements the craftsman makes in his work. The comparison of operations with craft trades helps one see the connections between body, soul and intellect in modern production”.*

The discussion this far can be summed up in Table 4.1, where Ellström (1996:24) has compared two different models in order to better understand the process operators’ work and competence.

**Table 4.1 Two models in order to understand operators’ work and competence demands**

Aspect		Models	
		“First thinking then acting” (rationalistic perspective)	Familiarity and experience (Intuitively-contextual perspective)
1.	Information as background for action	Certain Objective ends	Uncertain Holistic directed senses Experience
2.	Information treating	Analytical	Intuitively
3.	Action model	Technical instrumental Separation between planning and action: “Problem-solution-through thinking”	Interactive-contextual Interaction between planning and action: “Problem-solution-through action”, trial and error
4.	Knowledge base	Theoretical Explicit	Experience based Implicit (tacit)
5.	Communication/social interaction	Indirect, impersonal Instrumental: Information and directions to make others perform a certain task	Direct, personal Dialogue for common insights and decisions

Ellström strongly emphasises two matters of importance regarding the model:

1. It is a conscious simplification in order to demonstrate two ideal typical views within the work of operators.
2. The two models are not mutually exclusive. On the contrary they are complementary.

He states that both models are necessary in order to understand operators' work and the demands placed on them. But the two models will have different validity within different work tasks and situations. The experience-based model can be most appropriate

- to experienced operators
- under time pressure
- in more complex production systems
- to treat unstructured, unknown and less defined problem situations

while a rationalistic way of working can be more appropriate

- to less experienced operators
- to treat abstract information
- in more linear production systems
- when there is a pressure to legitimate decisions made
- to treat more structured, well-known and well-defined problematic situations.

In this section I have regarded different views of knowledge and found support for a main distinction between explicit and tacit knowledge. This difference is of great importance with regard to how process understanding can be developed. In the next sections I will go more into detail on how knowledge in process understanding can be regarded.

#### 4.1.3 Knowledge in process understanding

Ellström (1996) asks if the development towards increased automation has affected the process operator's professional competence. He states that some features seem to be common within highly automated process plants:

*“A number of studies confirm the features in operators work – increased complexity, fewer occasions of manual actions, increased level of abstraction- raise higher demands to theoretical as well as practical knowledge and intellectual skills. It is then not about taking rules of thumb that have been trained in order to solve tasks. Instead demands are raised to a higher degree of independence.... A theoretical based holistic understanding of the whole business is demanded in order to analyse new problem situations. Against this background, the term “intellectualisation” of operator’s work is often highlighted. A number of studies<sup>37</sup> give an answer in general terms to this pointing on:*

- *A deeper process understanding based on theoretical knowledge.*
- *An ability to make mental models of the processes.*
- *An increased ability to detect, identify and diagnose problems.*
- *An increased ability to planning, problem solving and decision making based on analytical-logical thinking and explicit knowledge (contrary to tacit knowledge that hardly or not can be expressed in words).” (p. 18)*

All these factors are important in controlling a plant. Zuboff (1988) has described the transforming of pulp mills from being manually controlled to being computerised and controlled from remote control rooms<sup>38</sup>. She emphasises the increased dependency of theoretical knowledge about the production processes and states: *“The mill’s workers knew how to do things, but they had little understanding of what they were doing and why”<sup>39</sup>*. In her argumentation she uses quotations from pulp mill workers. One operator formulates the need for knowledge the following way:

*“The more I learn theoretically, the more I see in the information. Raw data turns into information with my knowledge. I find that you have to be able to know more in order to do more. It is your understanding of the process that guides you. We need to keep refining and defining what we have learned. There is a difference between knowing the instruments and knowing the relationships and theories that connect things. We need to understand the relationships between density and volume and flow and pressure. It’s like knowing what it does versus knowing why and how. If you want to handle a problem, you have to want to know this.”(p.94)*

---

<sup>37</sup> Bergman (1995); Brehmer (1993); Buchanan & Bessant (1985); Bohle & Rose (1992); Davidson & Svedin (1995); Hirshorn (1984); Zuboff (1988).

<sup>38</sup> Parallel to what happened at Norske Skog Tofte in 1980.

<sup>39</sup> The situation in US pulp mills in the mid 80s according to Zuboff (1988).

Another operator at a pulp mill argues: “..And if you don’t know what to look for in the data, you won’t know what is happening”. A manager at the same plant explained: “....if they don’t know the theory behind how the plant works, how can we expect them to understand all the variables in the new computer system and how these variables interact?” (p.94)

Ullmark (1996:20) also discusses this issue. He argues that it became more evident as automation progressed that theoretical knowledge of physical, chemical, and biological processes is limited.

*“When processes are stable they are normally mastered. But in the case when one or more variables deviate, one has often problems in explaining theoretically what happens, predict all effects and think of effective ways of regaining control.”*

A distinction of different forms of knowledge is also found in de Montmollin & De Kayser (1985). These researchers differentiate between three kinds of process knowledge:

1. Knowledge of how the chemical-physical processes function, independent of how it can be controlled.
2. Knowledge of the processing in relation to the control systems, i.e., knowledge of how the processes principally can be controlled.
3. Knowledge of how the process practically can be controlled, what one concretely can do in order to gain certain desired effects.

Points 1) and 2) represent different forms of functional or theoretical knowledge of a more general character – “knowing that” and “knowing why”. The third point represents a more application directed knowledge – “knowing how”.

Traditionally, engineers have possessed type 1) and/or 2) knowledge, and operators type 3) knowledge. The differences between engineer and operator knowledge diminishes as a result of higher demands on the operators. Operators need to meet present and coming demands with more “engineering knowledge” in order to monitor and control processes particularly when deviations and unpredicted events occur. The process operator will to a higher degree be a link between theory/science and reality/practice (Ellström, 1996).

Olsson (1996:27) follows much of the same argumentation:

*“If operators are to handle new tasks as modern production technology demands, they need a much better theoretical basis. Operators simply need more “engineer’s knowledge” with emphasis on natural scientific and technical theories and models, relevant for the local process. Such a theoretical basis will serve as a cognitive map to which operators can relate their experiences and observations from their practice. Model knowledge, is however to be regarded as a basis, not as substitution of experience based knowledge. Model knowledge will give a background in order to understand which control variables that influence different state-and measure variables in the process, i.e. which controllers to be adjusted. But this knowledge does not say anything of how much to change, in what order or sequence and so on” This kind of knowledge is a kind of “process feeling” that can be achieved only through training and experience.”*

Olsson thus adds to those who emphasise the importance of knowledge of familiarity and practical knowledge in operations.

Perby (1995)<sup>40</sup> gives a thorough insight into what constitute process operators’ knowledge and skills in operations. A central conclusion in her research is that professional knowledge is characterised by an unbroken wholeness of issues related to each other, and connections that are essential to the practice and thereby impossible to separate. She says that operators think in terms of practical situations. They do not separate “process” from equipment. Everything is inseparably connected in order to make a good product: *“The world of professional knowledge does not follow the logic that is connected to the analytical way of thinking; it follows another logic.”* When talking to operators about knowledge, one has to leave stereotypical concepts of knowledge in terms of theory and practice, mind and body, mental from manual, concrete and abstract, she argues. An operator needs to be multi-skilled – a

---

<sup>40</sup> In a book titled “The art of mastering a process - about the administration of profession knowledge”. Her data are from two process plants in Sweden, a refinery and a chemical pulp mill. (This pulp mill has close to identical production technologies as Södra Cell Tofte). She states with her choice of title that there is much more in the operator’s knowledge than propositional knowledge and analytical skills. Perby uses experienced and well-educated operators (one is even engineer and has worked as designer) as informants to tell about their work. As a method the informants have gone through drafts of the book and reflected on and given comments to the theories. I gave the resume chapter (in Swedish) to the 9 educational responsible operators at Tofte and the 5 who responded recognised her theories.

counter argument to the cliché that their work is simple due to automated systems doing the job. An operator in Perby's study argues:

*“Operators need knowledge of the kind of material in use, how well it takes welding. One needs to be electrician, mechanics, control and instrumentations, welder, physician, chemists.” (p.99)*

Perby criticises what she regards as the one-sided emphasis on theory as the only salient feature in operations and the role theory has among researchers and managers.

*“Researchers' main interest is the mental, intellectual and cognitive in operators work. Managers states that theoretical knowledge is necessary for today's operators. The operators themselves speak in different terms of knowledge, knowledge demands and knowledge interest. When you listen to them, you forget the stereotypes” (p.99)*

she says and adds that *“theory alone is given so much attention that it tends to fill the whole view field”*. Perby's critique on the one-sided emphasis on theory is thus in line with that of Nonaka & Takeuchi (1995) on the general Western approach to knowledge. The experienced operators in Perby's study seem to have some difficulties in pinpointing the need for theory. One operator states after having thought it over that knowledge about chemistry is an advantage in order to understand developments in pressure and temperatures. Another operator reflects on what he has gained by reading process control and instrumentation for two years and chemical engineering for one year. He is supported by a colleague who states that he learns and understands more rapidly than others.

One operator in Perby's study claims he can distinguish between different valve characteristics by listening to them. The valve characteristics is however a typical example of dependence upon a theoretical concept. Different valve characteristics indicate that different valves will have different throughput given same percentage of opening position and other parameters kept constant. Without knowing this, the operator with knowledge of familiarity may distinguish between different sounds, but not between different valve characteristics. I will argue that the operator in this case has a theoretical understanding of the concept, but in conjunction with experience, it has become partly tacit.

In this section I have argued that the demands from the technical system such as increased automation increase the demands on operators' theoretical abilities. In order to be able to control deviations or even avoid deviations, they need to increase their "knowing why" abilities. But it is also emphasised that there must be a balance between theory and practice. Bainbridge (in Perby, 1995) emphasises this when she concludes that the task of monitoring and controlling really complex processes will take years to develop. Perby (1995) can be read as a counter argument to an unbalanced focus on theory while other writers presented this far in this chapter have a more balanced view as they emphasise the need for more "engineers" knowledge, but that this cannot replace practical and tacit knowledge gained by experience. I follow these writers as knowing why or a theoretical understanding of what takes place in complex process will become more important as the rate of change will increase towards more automated and complex plants.

In the following section I will examine more closely some of the aspects that are important in process control, before I make a summary of knowledge in operation.

#### 4.1.4 Aspects of knowledge in operations

This far I have treated various kinds of knowledge necessary in plant operations at a more general level, and in the following I will discuss aspects of process control and mental models in more detail.

One main task for process operators is monitoring the automated processes via information systems in a control room. At one end of a scale it may involve to wait for alarms to arise (a pre-programmed alarm signal; sound or change in data representation colour on monitor when a set point is too far from wanted value). At the other end it may involve to actively monitor and if necessary manually control the processes in order to keep as close as possible to optimal production conditions. An active operator will screen the different representations within his/her responsibility area and perhaps outside this area if he/she knows how neighbouring sections may influence her processes. Perby (1995) uses the term "aesthetics" in operation to denote a way of understanding and operating the plant in a smooth and careful manner. She says:

*“Aesthetics in operation: The concept contains much. It is the smooth production, the high product quality, and all process values that indicate good quality and good housekeeping of raw materials and environment. More than it seems to in the beginning, aesthetics in operation is about the equipment. That one treats the equipment with a careful hand is a precondition in order to make the processes proceed well. It is in the aesthetics to be on the safe side.” (p.148)*

One of Perby’s informants uses the concept fastidious in the selection of given information.

*“To be fastidious is about being conscious of small signs and having an ability to know what is important and what is not. In a complex process one will get many small and weak signs that may develop, but it do not have to develop”. As one operator says: “What this profession is much about is to detect weak tendencies. This is a matter that take long time to learn, not least to learn what will happen if one do not make any actions. An alarm is no solution in this case, it is to predict something long before one can pinpoint that a flow or a level is wrong.” (p.118)*

To operate a plant in an aesthetical mode and to be fastidious in the flow of information should be a goal for every process operator. A pertinent question is then how a process operator regards the process plant and the tools available for controlling it? The ability to make mental models is introduced as a desired operator feature. Perby denotes a mental model an “inner picture”. Operators change perspective between the abstract and the concrete, and the abstract may be thought of as mental models, according to Perby. She argues that operators do not see the representation on the monitors, they see the actual pump or controller in its surroundings out in the plant. Thus, I will argue that a mental model is what an operator bases his/her decisions regarding what actions to take, and therefore they must be discussed in more detail. Senge (1990) describes mental models as deeply held internal images of how the world works: *“No human being can carry the world in his mind. What we have are mental models of reality which we see the world through, and these models are always incomplete”*. I will restrict the further discussion of the concept in relation to a process plant. A mental model may have the following characteristics (Johnson-Laird (1983) in Booth (1989)):

- A mental model is a simplification of what it represents, and for that reason incomplete.
- It is unstable due to details that may be forgotten.



- It is used to make assumptions and to predict events in controlling a plant. Since the model most often will be incomplete, the assumptions and predictions may be wrong.
- It is not more complicated than it needs to be.

In a process plant a mental model may be regarded as a system and the system can include anything from a detail to the entire plant and the level of detail may vary. The mental models developed are linked with other mental models to form networks. A major challenge with a mental model is thus to make correct system limitations in order to study or analyse a specific task. Mental models are also represented in various ways. In Neilsen (1981) Bandler and Grinder argue that the three most common ways of representing models are visually, auditorially (by sound) and as activity. Most people have models made up of all three forms, but usually only one form is dominating (Jakobsen, 1994). Visual models are most common, but other models can be dominating as well. The mental models the different actors in the operation of a process plant have will vary depending upon relevant knowledge and experience. People with long theoretical education will often represent their models by abstract concepts, and also make abstract models where connections to a large extent are decided through analysis and reflection. Persons with practical experiences rather than theoretical knowledge, will to a larger extent make models that are based on these experiences. Generally, the more knowledge about a process one has, the more details can be put in the models, and the more complex and complete the model might appear.

Mental models, as discussed in this section, are personal and parts of them are tacit, as they in many cases consist of various experiences connected to the system covered by the model. As mental models are used to make assumptions and predict events in controlling a plant, the chances are high that such predictions will vary between individuals. Also because such mental models are personal and partly tacit, it can be difficult to share them with others.

In this section I have discussed process control and mental models. I argued that to operate a plant in an esthetical mode and to be fastidious in the flow of information should be a goal for every process operator. I also discussed the concept mental model as a way of relating to the plant. The mental models are personal and are made up of both theory and experiences, and thereby they are partly tacit. I will end this section with a definition of process understanding that emphasise what I regard as most important from this discussion of knowledge in operation.

#### 4.1.5 Summary of knowledge in operations

Modern computerised production technologies and economic demands of equipment utilisation have lead to increased demands and an increase in the intellectualisation of the operators' work. There are increased demands on "knowing why" in operations. I have also discussed whether theoretical knowledge is enough. In order to develop process understanding, local, detailed knowledge of the process and the process controlling systems is vital. Such local knowledge is acquired only through experience.

I will term knowledge and skills necessary for controlling a plant for "process understanding" and define it as "*the ability to predict what is going to happen*". This definition encompasses the vital aspects in controlling a process plant outlined in this section: In order to predict what is going to happen in a system, one firstly need to define the system boundaries. This system can then be regarded as a mental model. One must know and analyse input variables (know where and how to get relevant process information) and by this anticipate, like in a mental simulation, what will happen with the parameters within a defined time period both on a shorter and on a longer term. Different options may then be mentally tested including what will happen if no corrective actions are taken.

An ability to predict what is going to happen with the product, to process equipment, or any other process variable, has to be developed and refined in order to operate a process plant optimally. In the next two sections I will discuss different types of learning and combine this with the different kinds of knowledge presented in this section taking both constraints and possibilities that features of a continuous process plant offer into consideration when process understanding is to be developed.

## 4.2 Methods and models in learning

I hear and I forget

I see and I remember

I do and I understand

*Confucius*

In the previous section I discussed various forms of knowledge and found that there are two main categories of knowledge: tacit and explicit knowledge. Both forms are used for predicting what is going to happen, and as a logical consequence both forms of knowledge must be developed in order to control a process plant.

In this section I will present and discuss three main different types of learning:

1. Conventional methods
2. Experiential (problem based) learning
3. Collective learning

These three types are not definite distinctions and to some degree they overlap. This distinction will however serve the purpose of having a more structured discussion of the learning types that are present and that need development in process plants. I will start with what can be regarded as conventional methods.

### 4.2.1 Conventional methods in operators' education and training

The traditional and most common methods of developing operational knowledge and skills are through:

1. External and internal courses
2. Operators learning from each other in the control room and from contact with production management and other staff personnel
3. Apprenticeship which imply a master-apprentice relationship

Point 1 covers education both before an apprentice or operator is employed at a plant as well as education in parallel with working. Point 2 refers to what takes place to a varying degree in any control room, whereas point 3 will be similar to point 2, but includes apprentices who in most cases are young people with no or little experience from working in a plant. These methods can also be regarded as individual methods as they are directed at each operator and not at operators as teams.

I have argued that operators need knowledge in order to “know why”. The central question is then how good and effective these methods are when the goal is to develop process understanding. What happens when one learns? Bjørgen (1992:28) provides one explanation:

*“The real mechanism in learning is described by the cognitive process of “searching for meaning”. In practice this means to search for similarities between the new and the existing structure of experience. For the moment Piaget might have given the best description on this process through his model of adaptation. We have ourselves tried to empirically document the cognitive processes in oral verbal learning where the central tenet and conclusion is that learning is the search for relations of similarities between the new subject matter and the existing structure of experience. The result of this work is can be expressed by changes in the result of learning as well as by change in experienced meaning: meaning and learning is the same.”*

With this definition of learning one may better understand the importance of having some relevant practice before theoretical concepts are introduced, as theory without links to local application is of limited value for most operators. Conventional methods are often based on the model of the pupil as the passive receiver, often in a classroom or at a course. This may be effective for the teacher, but not always for the pupil (apprentice/operator).

Lave and Wenger (1990) argues that external courses tend to endorse theory. Göranson (1988) takes this point as he states:

*“The knowledge of experience bestows viability on theoretical knowledge. On the other hand, theoretical knowledge is essential to provide a direction for experience. Many of these complicated questions have previously been overcome through apprenticeship”.*

Apprenticeship is a well recognised method of education and recruitment. The apprentice will in his/her practical education most often follow one shift in a department and thus take part in the required tasks and get to know the depth in the departments<sup>41</sup>.

What the apprentice (or operator) learns is however very much dependent upon the explanations the “expert” operator provides. Olsson (1996:26) treats this subject:

*“The traditional method in gaining knowledge of a production department has been a master - apprentice practice. This learning method leads to knowledge of how different tasks may be solved, but not why a certain action leads to a certain result or the conditions that must be fulfilled in order to reach a desired result. The answers to such questions the operators must find themselves as they gain more experience, and many do so. However, this may lead to very individual answers, with the possibility for some commonality within same shift team.”*

Olsson questions knowledge and skills of the “masters” or “experts”. If the “master” is unable to provide, e.g., causal inferences, the apprentice's mental models might be too incomplete and sometimes even wrong. Thus, despite general and local theories and local training that are present today, the demands to develop more precise mental models are still in place.

In the next section I will discuss why leaning possibilities not always are utilised by discussing aspects of experiential learning in order to be able to identify and analyse critical steps in learning about process control.

#### 4.2.2 Experiential (problem based) learning

I have argued that mental models based on “knowing why” is a necessity in today's plants. Such models need to be developed and refined. They can be refined both by new theory on the subject and by experiences. An important aspect in operations is just to refine the mental models by learning from various experiences. Kolb (1984) has discussed the concept of experiential learning and given the following definition: *“Learning is the process whereby*

---

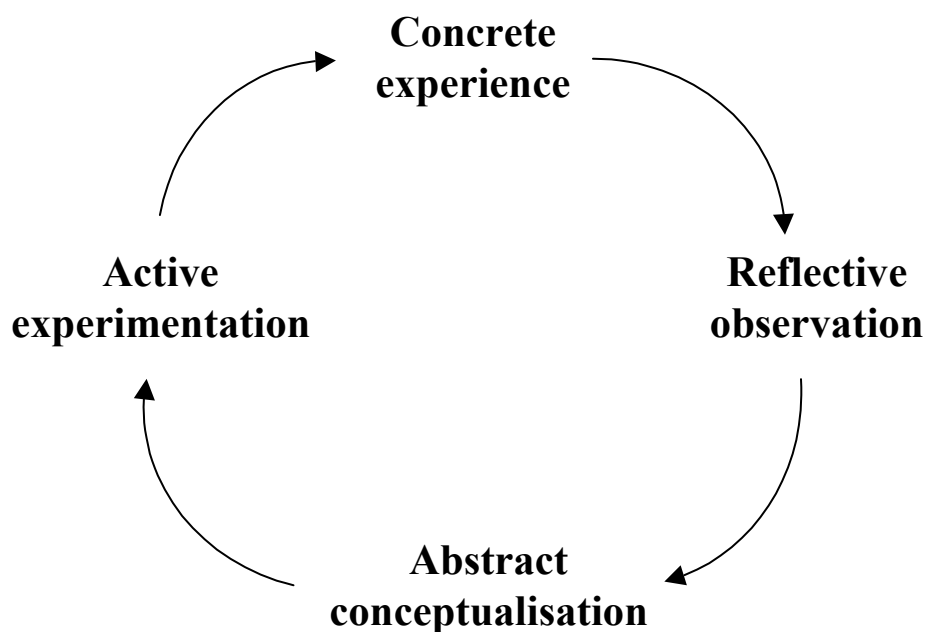
<sup>41</sup> This has been the traditional method of training within industry. However, in the 80s most industry in Norway also saw the necessity of strengthening theoretical knowledge. This was formalised in the industry with the official “trade certificate”. In order to raise the competence for adult workers as well, a parallel system was introduced also leading to the same certificate (“§20-candidates”). The content of this education is shown in Appendix 3.

*knowledge is created through the transformation of experience (p.38).*” According to Kolb, experiential learning can be regarded as a cyclic process, taking place in four stages.

*“By combining characteristics of learning and problem solving and conceiving of them as a single process, we can come closer to understand how it is that man generates from his experience concepts, rules and principles to guide his behaviour in new situations and how he modifies these concepts in order to improve their effectiveness”.*

This process is both active and passive, concrete and abstract. It can be conceived as a four-stage cycle:

(1) Concrete experience is followed by (2) observation and reflection, which lead to (3) the formation of abstract concepts and generalisations, which in turn lead to (4) hypotheses to be tested in future action, which in turn leads to new experiences, and so on.



**Figure 4.2 The Kolb experiential learning circle**

Kolbs’ definition is thus in line with Bjørgen (1992) on how we actually learn. However, Kolbs’ model is more detailed and provides a structure on how problem based learning can take place. He gives three general observations about this model of the learning process.

First, this learning circle is continuously recurring in people. Man continuously tests his concepts in experience and modifies them as a result of his observation of the experience. In a very important sense, all learning is re-learning and all education is re-education.

Second, the direction that learning takes is governed by one's felt needs and goals. We seek experiences that are related to our goals, interpret them in the light of our goals, and form concepts and test implications of these concepts that are relevant to our felt needs and goals. The implication of this fact is that the process of learning is erratic and inefficient when objectives are not clear.

Third, since the learning process is directed by individual needs and goals, learning styles become highly individual in both direction and process. An important implication of these points is that experiential learning leads to personal mental models if they are left by the individual and not organised as a collective learning process. The experiential learning model has the strength that it can explain the range of experiential learning from directly bodily felt experiences to cognitive experiences. It may thus yield experiences drawn from serious equipment failures to experiences drawn from feedback from a process outcome.

In the next section I will discuss some requirements that need to be present in order to learn from experiences.

### **Some requirements for learning from experiences in a process plant**

As the process of learning from experiences is broken down into four stages, and the four stages are oriented in a circle, all four stages have to be present if learning from experience is to be effective. There are thus a lot of fallacies that may explain why learning from experience in many cases does not take place within a plant. In the following I will discuss some of these that are relevant for learning about process control. First I will present a figure with explanation that will serve as example on my arguments.

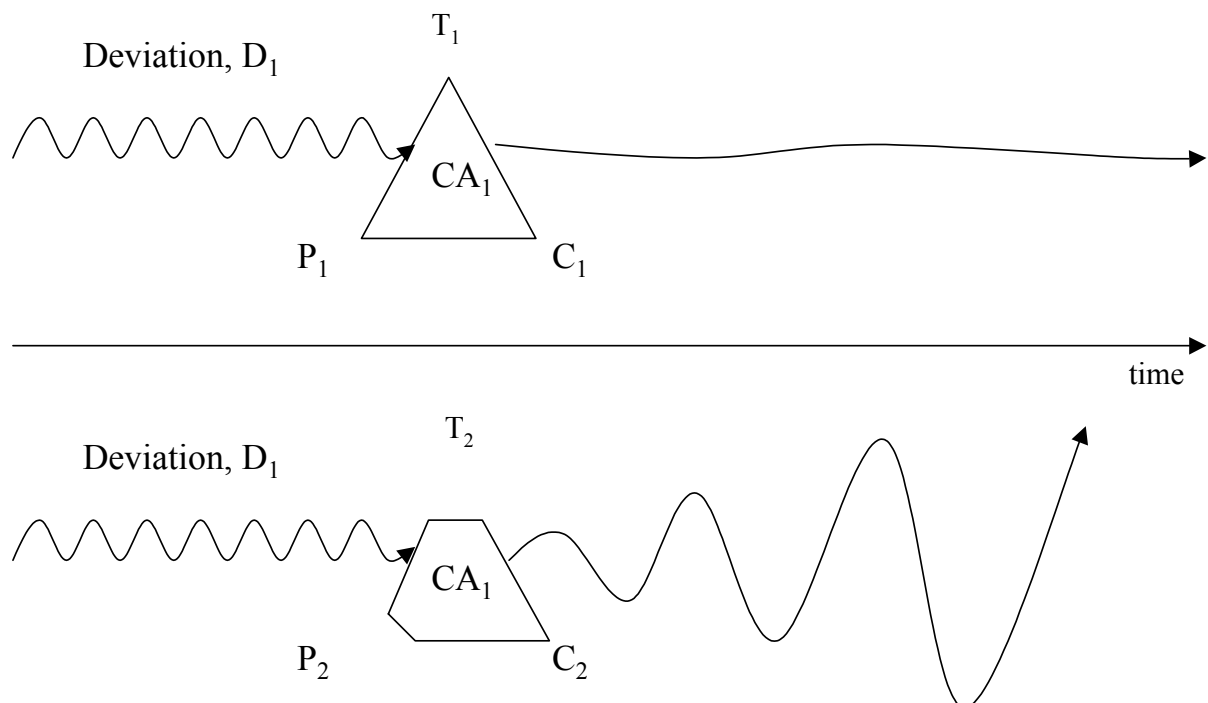
In the upper half of the figure a process is represented by a triangle with a given pressure  $P_1$ , temperature  $t_1$  and concentrations  $C_1$ . A deviation  $D_1$  is detected and corrective actions  $CA_1$  are made in order to calm down the disturbance. This turned out to be successful, and the operator thus may have learned that  $CA_1$  was a correct action in order to handle  $D_1$ . Now,

turning to the lower half, a time period has passed, and the same deviation  $D_1$  occurs once more. The operator once more makes the same corrective actions  $CA_1$ , and expects to have the disturbance under control. However, this time the process starts to oscillate ending in an integral windup.

### 1. Concrete experience.

A concrete experience can be in the range from burning one's finger on a stove to cognitive experiences, e.g., to be able to be fastidious in the interpretation of incoming signals to a defined system in a process and see a signal as something to investigate. *"The focus of the problem solving is on a specific problem felt to be relevant to the problem solver; it is, in fact, his involvement in the problem that makes it a problem"* (Kolb, 1984). Involvement in the problem is thus a central element in order to learn from experiences. He or she must show an interest in order to "see the problem" if it is not bodily felt or obvious, and this ability to "see" depends upon "knowing why" abilities.

In the above example, the deviation  $D_1$  and its implications was the concrete experience.



**Figure 4.3 Experiential learning?**



## 2. Observations and reflections.

What happened, and why, and what does it mean? In many cases it is obvious, but as discussed for a process plant, it is not always clear-cut what happened. This requires skills in making an analysis of what happened. The information will in most cases be represented on monitors in the control room and have to be interpreted. Some “knowing why” abilities need to be present in order to do this. An operator without “knowing why” abilities may learn how to operate by following given rules and procedures. He may also learn how to react and what actions to take in order to handle certain known deviations. This person may have problems with the proper handling of more complex deviations, and learning from experience will be difficult if one is not able to analyse the context of the situation. In a complex plant the context changes as a consequence of various disturbances. Thus a certain action that functioned well under one condition will not necessarily function given another context. This is what is illustrated in the above figure. What the operator did not handle was the new process conditions given by  $P_2$ ,  $T_2$ , and  $C_2$  when he remembered what he successfully had done the last time.

Abilities must be present in order to analyse the situation as well as the context of the situation. Reflections on action are thus important in the experiential learning in order to refine the mental model covered by the new experience.

## 3. Formation of abstract concepts and generalisations.

What conclusions can be made based on the above experience and analysis? The experiential learning model shows that one is dependent upon concepts and theories in order to explain the observations one make. If this ability is not well developed, events will be valid only in the specific context. The experience may be added to a mental model, but without the ability to link this experience to a more general model, the value of it is limited. In the above example the model was too simple and was not built upon causal inferences. The generalisation of the models was not tested.

## 4. Active experimentation.

In order to close the learning circle, active experimentation should be performed in order to get a new concrete experience that enables one to evaluate whether the abstract concept from the previous experience was correct. If the theories are not tested, one will not know whether they are valid or correct. Results from active experimentation serve as feedback in the

learning process and are essential to close the learning circle. Feedback can be given from the technical system. If the system now behaves normally, the next concrete experience will be a confirmation of just that.

The theory of experiential learning states that active experimentation is necessary in order to learn. Another pre requisite is proper feedback. This should be provided as early as possible as otherwise the context in the meantime may change. A complicating factor in continuous production is also the fact that the feed back may not be provided within the same shift and thus make a break in the learning circle. I will argue that developing abilities for predicting what is going to happen in a process, the model of experiential learning opens up for analysing more in detail what is actually needed both from each person, from the organisation, and from the technical system. I have discussed that there are several challenges that have to be coped with for learning from experiences to take place. One of these is the presence of “knowing why” and the ability to develop and refine mental models from the various events. This is also denoted by Brehmer (1987 (in Ellström, 1996)), as he states that learning through experiences also presuppose access to knowledge and mental models that help us identify and interpret the information that experience gives us. The other main factor is provision of feedback in order to close the learning circle.

### **Summing up**

This far I have discussed different views of knowledge in operations of a process plant and general theories of how desired knowledge and skills may be obtained through various forms of learning. The common methods of learning all have positive elements, but also some shortcomings. One is the development of personal mental models that are personal and to a large extent dependent upon the masters’ explanations. To what degree are these explanations, e.g., based on correct causal inferences? Another shortcoming is just how to provide more shared mental models between operators and shifts in order to align practice. The theories discussed this far have not treated this subject.

I will proceed with discussing the concept “community-of-practice” under the heading “collective learning” before I present the concept “learning arenas”, and finally discuss what type of learning that will take place within the various arenas. This discussion will lead to a refinement of my research questions.

### 4.2.3 Collective learning

I have thus far discussed individual learning. In a complex process plant there is also a need for shared or collective learning. I will discuss the concept “communities-of-practice” in order to give an explanation of a kind of learning that takes place at various levels and places in a process plant. I will return to planned educational efforts for collective learning when introducing the concept of learning arena.

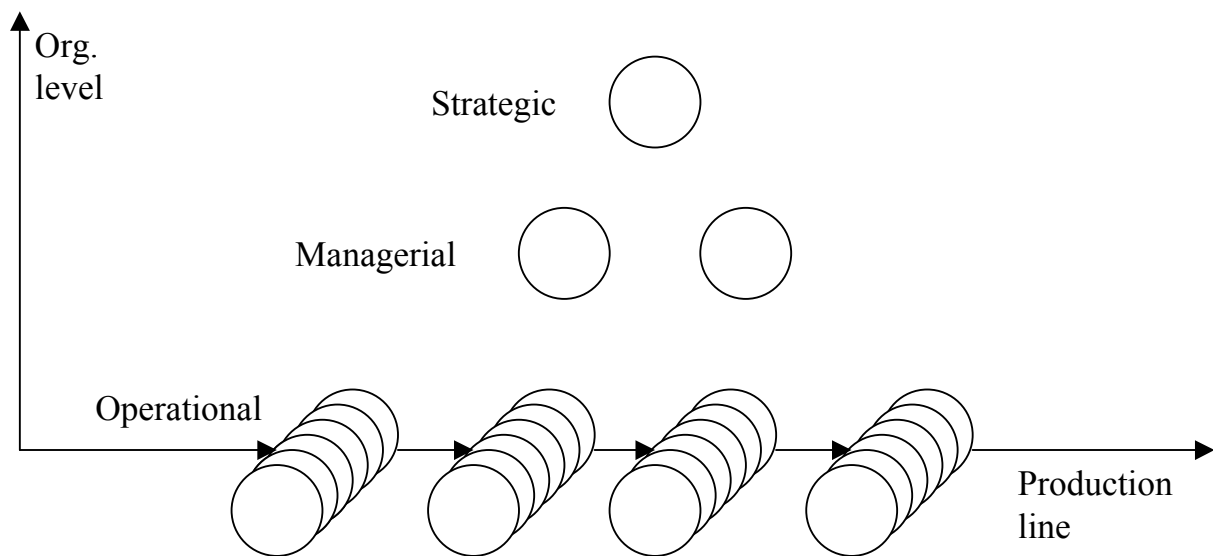
Figure 4.4 shows an organisation structured in three main organisational levels and with the operational level along the production line. Each circle on the production line represents a shift in a control room. The number of shifts and control rooms is dependent upon organisational choice and layout of the plant. Each circle in the figure may also be regarded as a community-of-practice. Brown and Duguid (1991) and Lave and Wenger (1990) use the concept of “community-of practice” to denote groups of people that share sets of experiences, goals and interests through common practice.

*“A community-of-practice is a set of experienced performers sharing a similar appraisal of situations, and a repertoire of actions, relevant to those situations. What is thus shared is certain ways of seeing and certain ways of acting.”*

According to Hendry (1996), communities-of-practice are the relationships people strike up to solve problems (though they may be influenced by formal role relationships as well). Brown & Duguid (1991), state that occupational communities in companies may constitute an ideal type of community-of-practice, and that an organisation may be construed as a set of overlapping communities of practice, a “community-of communities”. The various professional or occupational communities of practice are the most obvious organisational communities of practice<sup>42</sup>. In a process plant, a shift in a control room may constitute a natural group or a community-of-practice given the division in time (need for different shifts) and area (different control rooms). The control room is the place where operational decisions are executed and where experiences from production first are detected. It is also the place where knowledge and skills are to be utilised in order to control a plant.

---

<sup>42</sup> Husemoen (1997) uses the concept to denote differences between operations and design as two general communities-of-practice.



**Figure 4.4 A process plant organisation**

People are socialised into communities-of-practice through learning the language and reasoning of the group. Tacit knowledge emerging from the practice is shared among the people in the practice. Knowledge is embedded in the practice, and learning is a collaborative process not separate from that practice, Brown and Duguid argue. They see knowledge profoundly connected to the context in which it is learned, and linked to particular practice. Olsson (1996:27) points to this when he argues:

*“ It is a common practice in shift changes to make certain changes in set points from the preceding shift. When asking why, they say: “We do it in our way”.”*

Different focus of attention is an unavoidable phenomenon as people are involved in different practices, Skule (1994) claims. He further argues that the sharing of tacit knowing depends on participation in a shared practice and competence within the same language game (meaning of a word). As long as work division exists, and people take part in widely different communities-of-practice, it remains impossible to account fully for the tacit knowledge of the world across different communities. A top manager will never fully understand the tacit knowing of the world inherent in the lowest workers’ community, simply because their practices are widely different. In communities-of-practice people develop their own language game. Such learning cannot be shared through information or explicable rules, but requires

socialisation through some form of apprenticeship arrangement with a skilled master practitioner, which allows tacit knowing to be transferred along with explicit information. Even if the language of each community of practice on the surface seems to use the same signs as other communities of practice, the meaning of each sign will be constituted by the practice in that community, and therefore have a different meaning, he states.

Berger and Luckman (1966) argue that people interacting in certain historical and social contexts share information from which they construct social knowledge as a reality, which in turn influences their judgement, behaviour, and attitude. Schein (1993) argues in the same vein:

*“The problem of communication between different communities of practice increases the more different their practice is, that is the more the organisations differentiates itself in terms of functional groupings, hierarchical strata, project groups and other company based units.”*

A reduction in the numbers of hierarchical levels and differences between organisational units may be a result of the socio-technical system design, where the design goal is to find a joint optimisation or best match between the social and technical system.

I have argued that a shift in a control room may be regarded as a community-of-practice and that collective learning will take place within such a community. I have also argued that collective learning within a community-of-practice will vary. The theories of communities-of-practice may be a tool for understanding why such differences arise. A central process control challenge is to avoid such differences in practice between shifts. In the next section I will therefore discuss learning arenas as means to join various communities-of-practice with a goal to provide more shared understanding and practice.

### **4.3 Learning arenas**

I have this far discussed various learning forms that take place in a process plant, and will now provide a frame for learning in which both experiential and collective learning are covered.

The concept “learning arenas” constitute situations and places where various forms of learning processes can take place, i.e., arenas in which people can challenge their basic assumptions and reflect on their actions. As such both classrooms and control rooms can serve as physical settings for a learning arena. Elden & Levin (1991) define arenas as “*social situations that enables learning*”. Simensen (1998) extends the definition to include human interaction with technology as a process equipment or a control system, e.g. when an operator monitor or control a process. Greenwood and Levin (1998) regard arenas simply as locations where the involved actors encounter each other in a material setting between two or more people, a team building session, a search conference, a task group meeting, a leadership group meeting, or a public community meeting. The key point is that an arena allows communicative actions to take place, therefore I will in this thesis keep to Greenwood and Levin’s more restricted definition of the concept.

In order to develop new knowledge and skills, and try to align different mental models between various communities-of-practice, arenas, beside the control rooms and classroom settings where people from different communities-of-practice can meet and interact are needed.

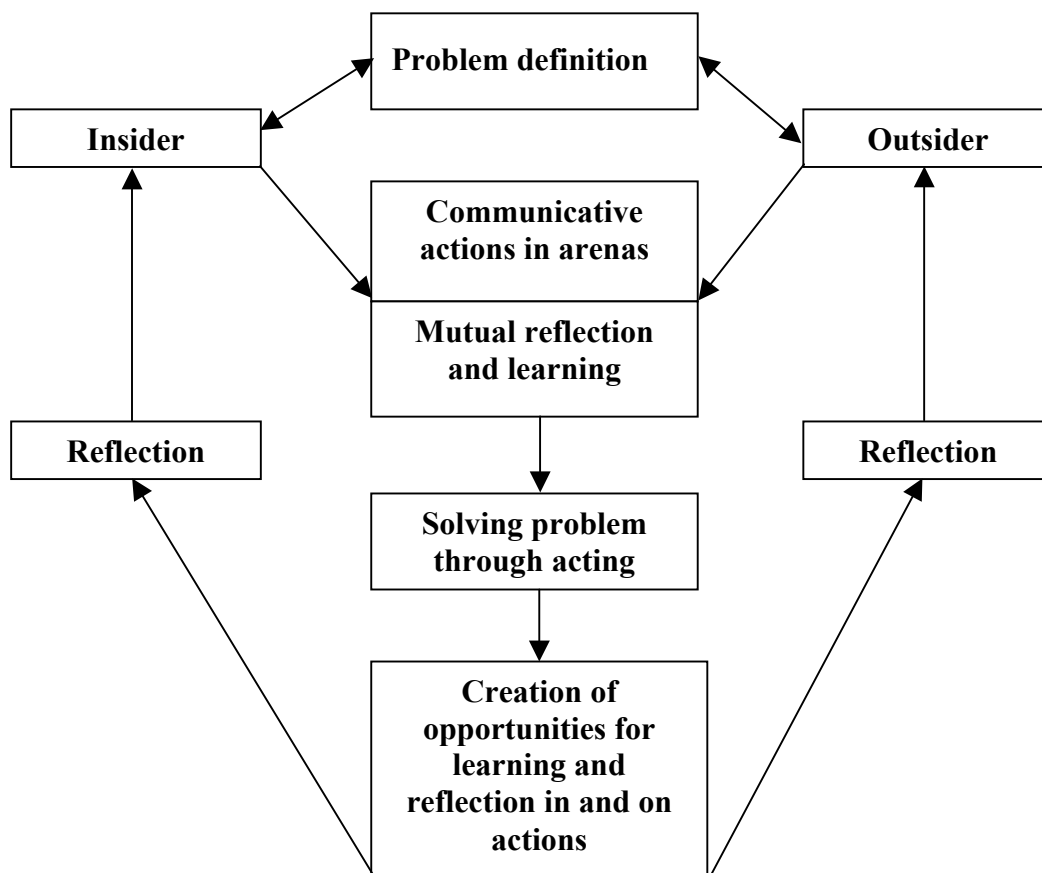
Greenwood and Levin (1998) have developed a model that is useful for explaining both the structure of a learning arena and identifying the actors’ tasks and the learning processes that may take place. The origin of the model is participatory action research, where the “outsider” is to be regarded as a researcher. The model has lately been refined by Greenwood and Levin (1998) and is given in Figure 4.5. Elden and Levin (1991:140) say that

*“.....we believe this model to be more generally relevant where people with different forms of expertise and frames of reference collaborate in creating a common conceptual field that makes possible collective action.”*

I will briefly present the model (conceptualise the learning arena) before I proceed to discuss learning forms related to various arenas.

A main feature of learning arenas is to join employees from the various communities-of-practice in order to solve a problem – the purpose of the specific arena. A learning arena is problem specific. Thus, prior to the meeting there must be a kind of “problem definition” – a

restricted theme for the arena. This can be a given production problem or a matter of optimisation/cost reduction. In order to solve a process control challenge, a learning arena must be designed to cover the most important stakeholders. It will in all cases involve all shifts within a control room and the managerial level. If the process control problem covers more than one control room, then the arena should cover the involved control rooms as well as relevant managers (confer Figure 4.4). The involvement of managers is necessary for two reasons: they are both providers and receivers of information in cogenerative learning, and they are needed to provide managerial support for proposals that may come up.



**Figure 4.5 A cogenerative learning model**

In a learning arena, “insiders” with their local knowledge from their community-of-practice will meet “outsiders” from other communities-of-practice. In a process plant the insiders will most often be process operators, but they may as well be mechanics of various kinds, depending upon the purpose of the learning arena. The outsiders will in this context most

often be process engineers or other managers who can provide more general context free theories, but they may as well be external consultants or operators holding other types of knowledge than the insiders. Thus a learning arena can be a place to provide explicit knowledge, like for example chemistry, to help participants to develop “knowing why” abilities. In a learning arena the theories will be problem specific and the participants may better understand why the theory is applied.

When following the model a frame is now provided where the insiders and outsiders can meet and participate in a cogenerative dialogue for mutual learning when the problem is discussed. This meeting will then be a community-of-communities where different experiences are discussed and meshed with more general theories.

The outcome of the arena can be local theories such as new or refined mental models. The insiders, who will be “the executers“ of new theory, must test these, e.g. perhaps change their practice. The outsiders, who can be for example process engineers, will be provided with local theories and explanations that may help to enlarge their often more general mental models. Such local knowledge is required in order to effectively help solving problems and assist in optimisation attempts. This is the clue in the concept of co-generated learning between insiders and outsiders.

Learning is individual, but as already discussed, collective actions in order to avoid differences in operations between individuals and shifts are important to organise for. A learning arena can create opportunities for learning and reflections in and on actions. In the cogenerated model there are arrows that close the learning circle. If the collective problem solving through acting for some reason fail or fade out before any measurable results are found, the learning will be limited. Unless theoretical concepts are tested, they will be forgotten for most participants, and the primary aim; to increase the ability to predict what is going to happen in the production system, will not be fulfilled. Closing the circle with proper testing and feedback is therefore of utmost importance. The outsiders who often are more trained in extracting knowledge from discussions may have got new insights, but their learning will also be limited if none of the agreements are tested in practice.

Feedback on how well the arena functions may also be given; e.g.: Was a topic too little problem oriented? Was it too poorly prepared? Were the participants unable to find any tasks



to be implemented? and so on. The arrows pointing back to the problem definition also indicate that the problem is not given once and for all, but sometimes it must be refined, as more knowledge and experience about the current problem is identified.

I have discussed the concept of community-of-practice and that differences in operational practice experienced in these may be met by having learning arenas where participants will meet in a dialogue and find shared explanations and theories that need to be collectively tested. In the next section I discuss what type of learning that may take place within different kinds of arenas.

#### **4.4 Learning types related to different types of arenas**

In this final part I will discuss the three methods conventional, experiential, and collective learning, and how these relate to different kinds of learning arenas. The major goal in a process plant is to get a skilful staff as quickly and cost effective as possible, and then maintain and develop the various kinds of knowledge presented in this chapter.

The typical arena for conventional methods is the classroom where an instructor offers theories to the class. This can be the most convenient method, e.g., in connection to projects when there is a need to inform a group of operating staff. (Ellström, 1996:33) presents four different approaches to how operator learning best can be performed in order to overcome shortcomings in traditional educational forms:

**Table 4.2 Requirements for learning**

1	Originate from problems and developmental needs in the plant.
2	Based on the individuals' experiences from problem solving in practical situations.
3	Made in forms that enable dialogue between and within different groups of personnel and between personnel and experts within different areas.
4	Planned and performed in co-operation with those who are directly involved in the education.

A brief criticism of traditional educational methods will be that they often do not meet these four requirements. This does not mean that traditional methods like classroom teaching should be abandoned, but that they always should be critically judged and that as many as possible of the four requirements should be taken into consideration both in the planning and conduction of education. However, the challenges in a process plant is to combine the four requirements for learning with the necessary requirement for effective learning to take place both within a shift in a control room and that of shared learning across shifts and hierarchical levels.

I have identified the shift in a control room as a central learning arena. This is where all theories must be tested and where feedback from the physical process is received. This is thus the arena where experiential learning at individual and group level will take place if the necessary requirements are present, such as a basis in process understanding. The experiential learning cycle describes how individuals may learn. Kolb (1984) originally developed the model to describe individual or group learning, but it might as well be used as a model of organisational or collective learning. The cogenerative model provides a frame for how communication can be provided both within a community -of-practice (the shift in the control room) and across communities-of-practices. This model can be seen as an extension of the Kolb model with the major difference that the co-generated model yield groups of two or more people.

Experiential or problem based learning will be individual, and it must be tested in the field and/or in the control room in order to receive feedback from the production equipment. Problem based learning, e.g., failures in production, is a very good point of origin for learning. Thus the learning arena will be the control room, often in combination with production equipment in field.

As previously discussed, due to different operational practice between shifts in addition to the complexity within different plant sections, there is a need for collective learning across shifts and departments. A learning arena can be organised where relevant operating staff can discuss new theories, how these fit with practice, and develop their mental models. Development and sharing of mental models is thus a major goal within a learning arena. In such an arena, the four requirements for learning given by Ellström all have a possibility to be met. Collective learning according to the cogenerated model may also take place in a control room. In that

model a master operator can be regarded as the outsider whereas the more inexperienced is the insider. The outsider may be an engineer or other operating staff taking part in a problem solving effort in a control room.

Another aspect of learning is the distinction between adapting (lower order) and developing directed learning (higher order). Some characteristics of the two modes of learning are given in the following table (Ellström, 1996:28).

**Table 4.3 Adapting and developing directed learning**

<b>Adapting directed learning in order to:</b>	<b>Developing directed learning in order to:</b>
<ul style="list-style-type: none"> <li>• Perform work tasks related to a distinct part or component</li> <li>• solve tasks that are experienced earlier</li> <li>• perform measurements or controls</li> <li>• have a restricted role or responsibility for given work tasks</li> </ul>	<ul style="list-style-type: none"> <li>• perform work tasks related to the whole system</li> <li>• formulate a problem, analyse the origin of it and how it may be solved</li> <li>• critically judge measured values and make proper actions</li> <li>• take responsibility for a bigger area or processes</li> </ul>

The lower order learning means that an individual or a group learns something from given tasks, goals, and pre-assumptions without questioning them. In higher order learning tasks, goals and pre assumptions should not be taken for granted. The individual or group should take responsibility for identification, interpretation, and formulation of the task. If this is given, one starts with investigating the meaning and the background for the task, its relevance and other given pre assumptions. Instead of just asking the question “How?”, the questions “What?” and “Why?” should be raised. The two modes are complementary rather than mutually exclusive, and learning needs to take place in both modes.

Ellström argues that learning in a process plant should be more directed against developing directed learning. In a learning arena where the four learning forms in Table 4.2 are taken into consideration, more developing directed learning is likely to take place. The two arguments, “to formulate a problem, analyse the origin of it, and how it may be solved” and “to critically judge measured values and make proper actions” can be regarded as requirements within the definition of process understanding as “an ability to predict what is going to happen.”

*“Much industry work has for a long time been dominated by lower order learning”*, Lundquist (1996) argues. Means should thus be created for higher order learning in order to cope with the challenges the industry has to meet. Proper use of learning arenas will thus be a means for “developing directed learning” in order to develop process understanding. This is clearly a challenge in the process industry. How this challenge is taken at Tofte, will be a matter of discussion in the analysis of the two learning cases at Tofte.

#### **4.5 Summary and research questions revised**

In Chapter 4.1 I presented theories of what constitute process operators’ knowledge and skills in highly automated remotely controlled process plants. The theories states that a variety of knowledge and skills is required and that some skills can be acquired only through years of experience. The “knowing why” within a process plant also has to be strengthen in order to develop better process understanding, but as an addition to the experience based “knowing how”. I have further discussed the experiential learning model and what may inhibit learning from experiences to take place in a plant. I have defined the concept “learning arena” and regarded each shift in a control room as a main learning arena since this is the place where theory meets practice. Further I have shown that practice will differ between shifts within same control room due to different mental models of the process. In various learning arenas, different communities-of-practice must be joined in order to make more shared mental models with the intention to align different practices.

In Chapter 6 I will present two main models of how to practically organise for learning taking both “knowing why” and “knowing how” into consideration, before analysing the two main models in Chapter 7 by answering the research questions outlined below.

From the introduction, my first general research question was:

##### **1. What are the learning systems for workers in a process plant?**

I will relate this to Tofte and briefly repeat the shortcomings of more traditional systems and how they relate to conventional methods (classroom, courses, etc.). This will then be contrasted with the learning systems presented in Chapter 6 on how the learning arenas in the

Tofte case to a larger degree support collective and experiential learning and thus follow requirements for better learning systems.

I have also presented socio-technical system thinking on how work in a process plant according to this paradigm can be regarded, and contrasted it with the old hierarchical system or paradigm. I have argued that managerial tasks in the new paradigm need to be changed, and that managers to a larger extent should be facilitators for learning. I will analyse how the use of learning arenas at Tofte give meaning to the concept of boundary control and how managerial tasks may be better structured by using learning arenas based on collective learning. Tofte's challenge of co-operation and responsibility distribution will also be a theme here. How operators knowledge and skills can be better utilised and thereby developed is also a matter to be analysed in this section. Thus my next question will be:

## **2. What is the implication for learning of different socio-technical structures?**

As all systems and models can be improved, I will, based on experiences from Tofte in my third and final question analyse:

## **3. How can learning be further improved for workers in the process industry?**

One definition of learning is increasing one's capacity to take effective action (Kim, 1993). Thus, if any learning has taken place, this should be traced in production statistics. I will analyse to what degree new organisational practice has led to improvements in production results. Based on this, I will suggest what kind of actions, and how these actions should be undertaken at Tofte. In this context I will regard both structure and content of the arenas as well as organisational and managerial practice.

In the next chapter I will give an outline and discussion of the research methods I have used in order to learn about the above outlined questions.

## **CHAPTER 5**

### **RESEARCH METHODS**

In this chapter I will outline the research methods used in order to answer my research questions. I will describe how I have been working in the research field, and how I will claim for the validity of my theories and conclusions.

#### **5.1 Introduction on research design and applied methods**

At Tofte the research questions were not given beforehand, although topics were identified and the wish that the researcher (in this case me) could act as a “change agent” also was expressed (IR: Gravdal, 1994). In action research, the researcher’s values and intentions become central for the research process. My research choices have been guided by my intentions to improve the co-operation in the organisation, develop means to improve process understanding in the production department, especially for the operators, and means to employ new, improved knowledge. In my feedback of theories from the learning arenas I have had the intention to make the organisation self-sustained with change and learning capabilities. The concepts of participation and democratisation as direct involvement of process operators are covering terms for what I have tried to pursue. Instead of trying to be an objective observer, which I will claim is impossible, I have been open with my intentions in the organisation.

My interventions with the organisation have been guided by action research (AR) methods. For a short description of what AR is, I refer to Appendix 9. I will now argue why my applied methods are much more in line with empirical methods.

The learning activities that turned out to be the core of this thesis started summer 1996 from an initiative by the production manager. As a researcher I was not involved in the planning phase leading to the start of these projects, and it was not planned as a research project before it started. When regarding AR as cogenerative learning (Greenwood & Levin, 1998), the researcher is “the outsider” in the learning model. I participated in learning events, but my role was not discussed as such in these sessions. And to the stakeholders I was at that time not

the “researcher”, but evaluating the “Employeeship” project and secretary of the educational council. They did not know initially that they were a part of a research design, and in AR the researcher and the stakeholders together define the problems to be examined, cogenerate relevant knowledge about them, learn and execute social research techniques, take actions, and interpret the results of actions based on what they have learned (Greenwood & Levin, 1998). In addition to this, my interactions with stakeholders in the learning programs have been modest. I will discuss this below.

However, my research has been in line with empirical work, inspired by action research elements. I will describe how I designed my research and the various methods I used. In the following section, I will describe types and extent of data, different roles and tasks I have had in the organisation during six identified time periods.

## **5.2 Types and extent of data**

### 5.2.1 Roles and interactions with Södra Cell Tofte

My different interactions with Tofte can for analytical reasons roughly be divided into six periods. These are given in Table 5.1.

The first period As a newly educated engineer from the chemical engineering department at the Norwegian University of Science and Technology, I learned much about production “in practice”. At that time I had not read any organisation theory and had no idea of concepts about socio-technical system thinking. However, I was sensitive to what I felt was lack of co-operation and sub-optimisations between departments. This industrial background was important for me to see the strengths and benefits of the INPRO model. I left Tofte just before the big reorganisation and downsizing project (“B-91”) started, and thus, I was not connected with this event when I returned to Tofte in 1994.

#### The second period

In the summer of 1993 I was contacted by Tofte and asked if I could be interested in participating in INPRO with Tofte as “my” plant. After being formally accepted by INPRO, I

was employed for a period by Tofte in order to develop educational material according to the educational model “LOOK 92” which Tofte at that time tried<sup>43</sup> (see Chapter 2.5.2).

**Table 5.1 Different research periods and roles in the Tofte organisation**

Nr.	Period	Role and tasks
1	June 1988-June 1991	Production engineer in the recovery department.
2	Spring 94	Developing educational material for the recovery department.
3	September 1994 - May 1996	Participating in necessary academic courses and INPRO activities. Stayed in Trondheim most of the time but kept close contact with Tofte in order to learn and develop research questions. Between the academic courses I stayed at Tofte in order to develop research questions and learn about Tofte.
4	May 1996- May 1997	Official leave from the INPRO project in order to evaluate an organisational development effort at Tofte. (“Employeeeship”)
5	May 1997- April 1999	Data collection and thesis work. Stayed most of the time at Tofte.
5	April 1999- November 2002	Worked as shift manager at Tofte while I finished the writing of the thesis.

### The third period

This period encompasses the main activities in Trondheim when I followed academic courses both at the institute of Organisation and Work life Science and other INPRO courses. As an important part of INPRO, we immediately started to develop our research questions and discussed these in the INPRO community. As a part of the academic course “Research methods” taken spring 1995, a research proposal was developed. I followed parts of this during the summer of 1995 at Tofte in order to collect and analyse data regarding my early research topics. At the end of this period I spent three months in Norfolk Virginia at Old Dominion University, Department of Engineering Management.

<sup>43</sup> For personal reasons this period which was supposed to last from April to 1 September was interrupted in the middle of June.



### The forth period

The normative PhD period is three years. This is a short time when academic courses take half of the time. In order to prolong my contact with the plant for a period of one year, I got a leave from the INPRO project to work full time at Tofte in order to evaluate an organisational development project called "Employeeeship".<sup>44</sup> This project was in line with the intentions behind INPRO that there would be an ongoing project that the INPRO candidate could follow. During this period, I stayed at Tofte full time.

### The fifth period

The distinction between the forth and the fifth period is not very sharp. As a part of my engagement in the evaluation of Employeeeship I developed theories on different learning arenas and entered these into the final report (IR: Stendal, 1997). During the fifth period I was active in the organisation with further theorising on the use and development of learning arenas in order to help to increase the process control of the plant by supporting organisational self-helping activities.

### The sixth period

In this period I worked as shift manager in the production department at Tofte – right in the middle of my research field. I had not been able to finish the thesis writing before I had to start this job. I had stopped the data collection and used free periods in the shift cycle to write the thesis. Work and family made this period much longer than intended. I will return to this period when I discuss the validity and reliability of my theories.

I will now describe how I have worked in the field and with my findings by organising the presentation using the six defined time periods.

## 5.2.2 The importance of the two first periods

The first two periods provided me with experience from the plant and thus background for writing this thesis. In the first period I learned that production is a highly integrated task, and at university the importance of learning how to learn. I experienced that it takes time to become “native” in an organisation, and it takes time to learn the local production systems. I

---

<sup>44</sup> This project is more closely described in chapter 2.5.4.

also learnt to work together with process operators and realised that they were the ones that needed knowledge and skills in order to operate the plant independently on an everyday basis. It was also a great benefit for me that I knew much of the local production systems, most administrative and production managerial people, and the organisation before the reorganisation in 1992. It has also been helpful to reflect on my own practice in this period and my lack of organisational concepts when I later on have discussed such matters in the organisation.

In the second period it was particularly interesting to work with development of educational material. At that time it was a part of an educational project called “LOOK 92” (see Chapter 2.5.2). This work provided me with knowledge of how this model (did not) functioned, and provided me with experience and tacit knowledge to better understand what the process operators, who later on took over this task, had to deal with.

### 5.2.3 The third period - early theory development

As a part of the INPRO model, the 9 students were encouraged to start the process of specifying research questions as soon as possible and then present and discuss them with each other in the INPRO community. This development was discussed in Chapter 1 and will not be repeated here. In order to make research proposals (first drafts), I spent a period at the plant around Christmas 1994 and conducted 8 interviews in a vertical slice of the production department and attended one weekly meeting with the shift managers in order to find relevant research fields. This was an open sampling.

As a part of my research design I was advised by my superiors to get a “reference group” at the plant. Together with my superior and my contact person at Tofte (the organisation and personnel manager) we decided that the group should consist of the production manager, the organisation and personnel manager, the leader of one of the production departments, one shift manager (the group selected their representative), and the operators’ trade union leader. I had thus direct access to the top management of the plant and the production department.

In the minute of meeting from the first meeting that was held in April 1995 the following issues were agreed upon:

- Give acceptance for research activities in the organisation.
- It will be a forum where important choices regarding the research can be discussed.
- Through my communication with the group (feed back of findings), the relevance will be improved.
- The use of the group will give me push to bring forth results that can be communicated to the reference group.
- A status report given as a call for meeting and further progress will be on each agenda.

During my research periods we have had 5 meetings. These are given in Table 5.2 and I will return to each of them as they appear chronological in the defined research periods.

**Table 5.2 Reference group meetings**

Datum	Main items
March 29. 95	Feedback on early draft on research proposal and agreement on reference group tasks and purpose <sup>45</sup> .
Sept. 19. 95	Presentation and discussion of findings from research made during summer.
Nov. 30. 95	Change of research focus to knowledge and learning. The reference groups' visions of necessary changes at Tofte.
May 13. 97	Learning arenas as tools to develop new knowledge and utilise operators' knowledge and skills.
April 3. 98	Feedback on research findings.

In the first meeting I got confirmed that my first (vague) research areas was of interest and that I should learn more about them during the summer mapping. As part of the INPRO-model I stayed 6 weeks during the summer at Tofte in order to learn more about the research topics communication and information in the production department. Since I was familiar in the organisation, I could move freely around without having to ask for permission. During the summer I applied the following methods:

---

<sup>45</sup> In this meeting my superior was present. In the third meeting both superiors were present, while at the last meeting my co-superior was present.

Interviews with: Production manager, assistant production manager, 3 shift managers, two department managers (Wood and recovery), the four process engineers, the manager in section of quality and technical customer support, the quality assurance manager, and the project manager. The outcomes was transcript and field notes. Besides this I spoke with/interviewed my contact persons in the department of organisation and personnel. Topics here were mostly planning of the Employeeship course. I spent several hours with the operators' trade union leader, since we drove together 70 km to and from Tofte every day throughout most of the summer.

In addition I spent time in control rooms and interviewed process operators. I covered 4 shifts in three control rooms. The outcome here was field notes. I also participated at 7 different production meetings in order to learn more about information and communication in the production department. Other methods were observations and study of documents. Especially the detailed production plan written by the production manger was important in order to learn what he regarded as major production challenges.

I made an extraction of the research during the summer and my findings were gathered in a 7 pages report that was to be discussed with my reference group in our second meeting. The report was distributed prior to the meeting, and at the meeting I presented my major findings. My main findings from research during the summer 95 are summarised in the following points. They were a blend of questions and statements:

- The focus of my further work will be on the organisation's interplay with technology.
- The process operators need knowledge about production processes in order to know what kind of information to ask for and to know what kind of information to give. This is a requirement for good co-operation and communication among colleagues.
- Knowledge of market and customers are lacking in major parts of the organisation. Is this important to know when it is an espoused theory to become a rapidly changing organisation?
- Given Tofte's way of organising the production section, how is knowledge exchanged between shifts (operators) and daytime resource persons?
- Utilisation of time while on shift. Are the operators encouraged to perform production improvements?

- Optimisations. Are these initiated by the production management?
- Minor use and push in using a maintenance planning IT-tool (MERIT) where the operators can write and thereby inform about any equipment failures during a shift.

What I also had found was that Tofte neither had any good grasp of experiential learning nor any good model for education of process operators besides the trade certificate education and training. From my data and my personal experiences as a production engineer, I found that the process engineers had difficulties defining their tasks given the present organisation, in particular regarding interactions and development of process operators. I also became aware of the structural difficulties between shift and daytime personnel regarding exchange of experiences.

At the second reference group meeting, my findings were confirmed. I also raised a question on how I could practically do something in the production section. I suggested to follow up eventual efforts created in the coming Employeeship courses, and this was also agreed upon. As a member of the reference group, the production manager had this analysis in mind when he five months later presented his wishes for the production section at a conference held at Leangkollen prior to the start up of the Employeeship courses.

#### *Third meeting with the reference group*

In the third meeting with the reference group in November 95, my two superiors also were present. Based on my findings and own development, my research focus had changed more in the direction of learning in the production section. I presented a model of learning between process engineers, operators and shift management. I had also asked the members what they regarded as necessary changes at Tofte in order to stay competitive. The debate started with a rather negative focus on reduced manning. However, after constructive arguments from the trade union leader, the emphasis shifted to how to develop the employees. And my emerging research focus on the need to develop knowledge in the production section was thus confirmed.

During this period I started to get theoretical insights into the fields of socio-technical studies and action research. Before I gained a grasp of relevant concepts, it was difficult for me to formulate precise research questions. According to Eden and Huxham (1996)

---

*“... the researcher should have a strategic intent for the research project. Indeed since action research will almost always be inductive theory building research, the really valuable insights are often those who emerge from the consultancy process in ways that cannot be foreseen.”*

I had my intentions in place, but not having concrete questions to follow was frustrating at that time.

#### 5.2.4 The forth period – Employeeship

My forth main period at Tofte covers the main body of my work with the organisational development project Employeeship. The project itself is not the main focus of this thesis, but it is important as a background context, and my working with the project provided me with rich data and possibilities for interacting with the production department. The project is therefore described in Chapter 2.5.4 and Appendix 4.

My main INPRO contact at Tofte was responsible for organisational development and thereby for this particular project. He regarded it as beneficial for the project to have a person dedicated for documenting and evaluating the project and feeding back theories. During this period I had a leave from INPRO for one year, and during that time I was employed by Tofte. I also was appointed as secretary in an educational council, and thereby I got the opportunity to write all minutes of meetings from events related to educational matters that at the same time could be regarded as follow up activities of Employeeship.

#### *My tasks in the Employeeship project*

I had the opportunity to play an active part in the Employeeship project because I was appointed to evaluate the project, and thus I could provide feedback on theories and results as the project moved on. As follow up activities in the project were not pre-planned, but rather had the character of ideas from the production manager (see the list in the introduction), I searched for connections between ongoing activities and the Employeeship project.

From the beginning I chose an action strategy by being active in the field as I saw this as the most appropriate strategy in order to make the change efforts come through. Experiences and theories were collected in a report that was given to all employees at Tofte in September 1997 (IR: Stendal, 1997). In the introduction I listed 6 different purposes with the report:

1. One definition of learning organisation is: *“An organisation which has made it as a distinct feature to learn from experience”* (van Hauen et al., 1995). The main goal is to present experiences from the project and leave it up to the individuals in the organisation to learn from these.
2. Give an overview of project content and the conduction of the project at Tofte.
3. Present and comment answers and comments from two questionnaires that all employees answered prior to and as a last point at each course. Present and comment results from SWOT-analyses (Tofte's strategy) made by all employees at each course.
4. Document whether the courses have served any purposes and contribute to the goals by presenting the documentation in a report.
5. Focus on changes. Can any actual changes in the organisation be ascribed to the Employeeship project? This is done by descriptions and analyses of seminars and new structures of working that Tofte has not tried before or that has been given a new focus.
6. Present plans for further follow up activities. These activity plans are a result from experiences drawn from Employeeship and presented for the top management group at two occasions. The first was in October 1996 and the second in January 1997. The last meeting also served as feedback to an early draft of the Employeeship report.

Table 5.3 summarises my interactions in different meetings in the project where Employeeship was the main topic.

**Table 5.3 Interactions and kind of data from the different Employeeship events**

Date	Event	Type of data
17 Oct. 1994	Participated in meeting with operators' trade union leader and three persons from org&pers. Topic: Need for and content in a course in "leadership" for all employees.	Observation, Field notes
10 and 11 Febr. 1995	Two day seminar at Vetre conference centre, Asker. 70 participants – management and trade union representatives. Discussing need for and content in a leadership program. I presented myself, INPRO, and my research topics.	Field notes, summary from the conference

Summer 1995	Participated in meetings with two competing consultants.	Notes
29 and 30 Aug.	Participated in one of three courses in “local laws and regulations” at Vetre, Asker. Content and topics in the Employeeship courses was a major theme as well.	Field notes
11 -13 Des. 1995	Participated in a three days seminar at Tofte where the structure and content of Employeeship was discussed. Participants were org. & pers., the Swedish founder, three Norwegian consultants, operators’ trade union leader, the IT manager and myself <sup>46</sup> .	Observation, field notes
Jan. 1996	Gave feedback on the of two questionnaires to be used at the courses.	
4 and 5 Febr. 1996	Participated at a two days seminar at Leangkollen, Asker. Same participants as on “Vetre 95”. The structure and content of the course was presented. Tofte’s Employeeship model was explained. Work techniques were practised in “What can I as a manager do to make Employeeship a success?”	Field notes
May 1996	Participated at course no. 6 out of 19 as an “ordinary” employee.	Field notes
Week 41	Attended a course as “observer”. My intention was to follow up the members of this course more closely afterwards.	Field notes
25 Oct.	Feedback meeting with Tofte’s top management group, org.&pers. and consultants.	Report from the meeting
22 Jan. 1997	New feedback session. Presented results from the two questionnaires and follow up activities related to Employeeship for top management group.	Feedback from management to be used in evaluation report
June 97	Two day seminar at Bolkesjø. Themes: Market plan, customer demands, pulp qualities, and the wood sorting project. I made a questionnaire and tied the seminar to Employeeship.	Field notes and evaluation report
Sept. 97	The final report from Employeeship was distributed to all employees at Tofte.	
20 and 21 Nov. 1997	Bolkesjø seminar. A seminar where follow up activities were presented and discussed and action plans for Tofte were made. I participated in the planning of the seminar and also wrote the report.	Field notes from discussions, group work and presentations. Wrote the evaluation report

All employees (383) completed a questionnaire with 7 statements prior to each course and a questionnaire with 19 statements just before leaving the course. Under each statement there

<sup>46</sup> It was at this time clear that I would take a role as evaluator of the project.



was two lines for comments. Written documentation from group work was produced in all courses. All the results from group work were photographed, and 4 to 5 weeks after the courses, the participants got the results.

In the report, results from the whole organisation were given along with comments on the degree of agreement with the statements. I also saw the importance of reporting the result from 19 times 3 SWOT-analyses. I also gave my own interpretation of the results from the SWOT analyses. That chapter of the report was given to the top management group in spring 1997 and became an important document for them in creating a new SWOT for Tofte. This SWOT is also given in the final Employeeship report.

Given my second formal role in the organisation as a secretary in the “LOOK 92” project under which Employeeship was organised, I was well positioned to participate in all educational and development efforts taking place in the organisation. According to my intentions of being involved in the Employeeship project, I was in search for evidence that follow up activities, in line with the intentions of the Employeeship project leader and production manager, actually were made. In other words, I found it important to connect theory with organisational practice. Ulbo de Sitter (in van Eijnatten 1993:181) argues that:

*“Although you cannot manage a human resource, you can indeed shape environments that mobilise human resources” and “STS-designers should look at themselves as architects of structure”.*

I found that such structures had to be constructed in order to create environment for change.

In the Employeeship project the need of individual initiative was stressed. However, there must be structures where initiatives can be transformed into new organisational practice. Along with the formal meetings from which I took notes, and often made minutes or reports, I made 25 formal interviews throughout the organisation, but with an emphasis on the project and production department. In the interviews with process operators I mainly asked for the outcome of the Employeeship course, and about possibilities for further professional development. In week 41 I followed a course as “observer”. My intentions were to follow the members of this course more closely afterwards as we would know each other better and have the same experiences from the course. Close to the entire group were followed up with

interviews. Data were transcripts of interviews that I returned in order to validate my interpretations.

Table 5.4 gives an overview of what I characterised as Employeeship follow up activities. It covers the time span I reported in the evaluation report.

**Table 5.4 Employeeship follow up activities**

Date	Event	Role / type of data
Aug. 1996	”Tofte 400 seminar”, Bolkesjø. Presentation of project plans, group work about process concepts and user participation.	Made a questionnaire and wrote the report. Participated in discussions.
4 Sept. 1996	Presentation at Tofte of educational model and practice in production department at Peterson Linerboard Moss. Group work on possibilities to adopt the model at Tofte.	Participated at the meeting. Asked questions about results. Wrote the meeting report.
21 Oct.	Meeting in the LOOK steering group. The Operator Training model central.	Invited the co-ordinator to the meeting and wrote the report.
24 Oct.	Start-up meeting regarding change of process control systems and design of control room in the recovery department.	Participated at the meeting and in group work concerning organising of learning. Took field notes.
7 Nov.	Information meeting to other operators of the educational plan related to the process control system change.	Asked if this project could be used to improve process understanding. Took notes.
19 Nov.	New meeting in the educational council. Development and progress in the Operator Training work.	Argued the benefits of the model. Wrote the meeting report.
5 Dec.	1. Operations Workshop in the recovery department.	Have given advises and feedback in the planning of the workshop. Participated at the workshop and asked for outcome. Took notes.
18Dec.	New meeting in the recovery department regarding construction of new process control pictures.	Observed and took notes from the event.
9 Jan. 1997	Start up meeting in change of process control system change on drying machine no.3. Similar to the recovery project.	Similar to the recovery project.
23Jan.	Operations Workshop in wet pulp department on continuous digester due to major process problems.	Participated and took notes.
20 Feb.	Operations Workshop at drying machine no. 3.	Received report and discussed with process engineer and operators on why it failed.

When I started the task of evaluating the Employeeship project I was at the same time searching for instruments with which the production section could develop new knowledge. As my theories on utilisation of learning possibilities in the production section emerged, I found it appropriate to combine my research goals with those of the Employeeship project. The participation in the Tofte 400 project was another possibility. As shown in Table 5.4, a new model of education and training of process operators was presented and discussed. This model seemed to be very promising<sup>47</sup>. The model presented relied very much on the process operators themselves. It soon became my strategic intention to argue for and support this way of working at Tofte.

In the writing of the evaluation of Employeeship project, I had every degree of freedom to emphasise whatever I wanted. My intentions by writing about the development and use of different learning arenas became clear to me: I wanted to describe the arenas in order to make them more visible in the organisation and thereby promote the use of them.

In April 1997 I had the final round of discussing the development of research topics and questions in the INPRO community. I had by then conceptualised the events at Tofte as learning arenas and found a shared focus at the arenas on operators' development. Regarding operators' development I used the concept "process understanding". We also had a brain storm on various definitions. After the meeting I was determined to use the concepts and regard learning arenas as tools for development of operators' process understanding.

In the forth meeting with my reference group at Tofte in May 97 I had given the members much of the same material as I had given to the INPRO community in April. It consisted of the chapter from the coming Employeeship report regarding the learning arenas and more details about the arenas. I had formulated 5 questions that I wanted to discuss at the meeting, and the most important was to get a confirmation on and conceptualisation of the identified learning arenas. I presented the goal as "*to integrate learning as a natural part of working by given and created possibilities*". I had made flow sheets of the arenas and discussed how Tofte could strengthen and refine learning possibilities through Operator training, Operations workshops and user groups. Another important issue that had been discussed at the INPRO meeting was the organisational and managerial context. In the discussion I raised, this was

---

<sup>47</sup> This model is presented in Chapter 6.2.

regarded as important to consider. By this meeting I had got a confirmation of my theories regarding learning arenas in the Employeeship report. I argued that Tofte via the learning arenas have tools for improved operator engagement and also that a broader and deeper process understanding might be a result. I had also grounded my main research questions, although a further refinement was required. I now had tools and concepts and could concentrate on learning more about the arenas by being an actor within them.

*The following up conference – “Bolkesjø 97”*

At the Employeeship feedback meeting in January 97 we decided to have a follow up conference. The evaluation report was distributed to the entire organisation in September, and the conference took place in November. The Employeeship project manager and myself made a proposal for a programme, and I suggested to involve the Work Research Institute in Oslo to discuss with us, so that it could take a form of a search conference. A search conference integrates planning, creative problem solving, and concrete action in the same process. This integration is its most unique feature, and it is a uniquely appropriate methodology for carrying out action research (Greenwood and Levin, 1998). Three consultants (including my co-superior) came and the final programme was closer to the search conference design than our original proposal.

The intention with the conference was to make concrete plans for how to work and cooperate in order to reach Tofte’s goals both on a shorter and longer term. This would be based on the experiences accumulated in Employeeship. My reason for being actively involving was to secure a broad managerial recognition of the identified learning arenas. The participants were almost the same as at the two earlier planning conferences: 64 managers, trade union leaders, and employee representatives.

The first group task was divided in three. The list of follow up activities and tasks from the evaluation report were given and three questions were raised:

- a) Discuss results this far
- b) Reasons for positive outcome and
- c) Improvements of the activities

The second group task that day was to discuss and prioritise five tasks in order to reach presented goals. Based on the group findings and presentations a group consisting of every trade union leader, two from organisation and personnel department and myself, made plans for day two. The task was “how to get from words to action”. Based on the list from group work 2, a 10-point list was made. “The winners” were:

- 1) Competence development
- 2) Preventive maintenance and
- 3) Use of and further development of Operations workshops

At day two, the participants could choose item freely. What turned out to be too difficult was to fulfil the requirement of making action plans with responsible people and time limits. However, my personal research intentions were met at the conference. In the evaluation report from this conference I highlighted important findings:

*“Focus on the need for increased competence. The tools Tofte has chosen for this task - Operator training, Operations Workshops, and project participation were strengthened at the conference”.*

The learning arenas were now widely presented and recognised throughout the organisation, and the emphasis of the importance of them as tools were given in the “winning list” where Operations workshops were mentioned by many groups and rated as no. 3 even though it was suggested that it could be treated under point 1) as competence development. The results from the various group work is used in my analysis of the arenas and how they can be further developed.

### 5.2.5 The fifth period – final theory building

In this period my main emphasis was on the learning arenas themselves and development of process understanding. My main interactions with the organisation in this period are given in Table 5.5. There is however no sharp distinction between forth and fifth period<sup>48</sup>, and table 5.4 and 5.5 can be read in connection.

---

<sup>48</sup> The distinction in time is made due to my different roles and what fell within what I reported in the Employeeship report.

**Table 5.5 Main interactions in the fifth period (May 97 – April 99)**

Date	Interaction	Type of data
May 97 – December 98	Participated in 6 educational council meetings.	Took notes, received minute of meeting.
November 27. 97	Participated in educational council extended by shift and production management.	Field notes, report from the meeting.
November 97 – May 98	Participated in 4 of 5 Operations Workshops (in the 5. period).	Field notes, observation, reports.
	Participated in 6 project user group meetings.	Notes, received minute of meeting.
3 April 98	Fifth meeting with reference group.	Notes, wrote report that was fed back.
28 April 98	Operator Training ceremony. The three first operators had passed a final test.	Made interviews and wrote an article that was printed in the internal newspaper.

### ***How I worked with Operator training***

As I had experience in the development of educational material at Tofte, I became eager when I heard of the coming presentation of an alternative model. In a rather thick minute from the meeting I wrote:

*“... Peterson Linerboard Moss’ value is that operators are valuable resources that have to be developed to the best also for the plant. The operators will get expanded job content, better possibilities for learning and development, and as a result a better working environment.”*

In the same minute I included a suggestion for structure and content of the new model made by the production manager based on the material and presentation from PLM.

In the next meeting in the “LOOK”<sup>49</sup> steering group, where Tofte’s top management were present, I got the co-ordinator of the emerging model to report progress and development in the work with the new model.

An issue that has been brought up in almost every meeting in the educational council by the educational responsible operators has been lack of managerial support to follow up candidates

<sup>49</sup> LOOK = Læring, Opplæring Og Kompetanse. See Chapter 2.5.2.

that show little or no progress. 15 months after the introduction of the new model it was decided to extend a meeting in the educational council with shift management. The theme was educational responsible operators' report on progress and eventually what could be done to improve the progress in finishing educational material. In addition I had asked them to report what they as educational responsible operators had achieved of learning and personal growth. My intention here was to provide the production management with more evidence that this model had to be supported.

As a research method I chose to participate at the meetings in the educational council in order to learn more about the model and how the educational responsible operators worked with it together with the process engineers. I also used this arena to present and test some of my emerging theories and give feedback to operators on their work. As I had learnt more about Tofte and I had got theoretical concepts of "knowing why" and "knowing how", I raised this topic in a meeting and we got a debate on how the Operator training model could serve the purpose of providing operators with "knowing why" knowledge. I also studied phase tests and found that in order to answer questions properly, both local equipment knowledge and system knowledge were required.

In another meeting I raised the topic of making a phase in each education program on consequences of deviations between departments as such knowledge is an requirement in order to inform about deviations in advance and for allowing an operator in another control room to prepare for the deviations. The council agreed that Operator training should contribute to increase such knowledge.

In the final phase of my research I used the educational council to confirm some of my findings. I presented the conclusion chapter in Perby (1995), and her findings were by five operators found to be valid for Tofte. I also used the council to confirm my definition of process understanding as "ability to predict what is going to happen" and later on the importance of knowing why and how regarding experiential learning.

I have followed the educational responsible operators and the co-ordinator closely with questions and discussions throughout the entire research period and provided them with positive feed back on the importance of their work. I have also kept close contact with the

process engineers to get their versions of development of the educational responsible operators and the candidates in the control rooms.

#### *The Operator training ceremony*

I participated at the Operator training ceremony and spoke with the three operators about the outcome, how they regarded the educational model and how to utilise new knowledge. I wrote an article from the event to Tofte's internal newspaper. In this article I also discussed how use of the Operator training structure the tasks between daytime (process engineers) and shift (operators and shift management). I asked for comments from the 8 participants before it was printed and by that confirmed that they agreed on my theories.

#### *How I worked with Operations workshops*

In December 1996 I participated at the first Operations workshop. Prior to this I had been given feedback and advises to the two process engineers in the recovery department on their programme. At the workshop I took notes and I learnt by interviewing the process operators that they regarded this way of working constructive. They also gave good feedback to the colleagues that were not present at the workshop. As I regarded this way of working as problem oriented learning that at the same time utilised operators' knowledge and experiences, I also wanted to learn whether this way of working could provide operators with process understanding. I soon realised, by interviewing process operators and asking for detectable changes after the workshops, that Tofte in most cases had problems with how to follow up tasks decided at the workshop. I discussed this matter with the process engineers in charge of the workshops and suggested that the final part of the workshop could be a discussion on how the findings from the workshop could practically be followed up and how to measure what is learnt from the workshops. By this I took active part in trying to change the structure of the workshops based on my findings at Tofte.

#### *The fifth meeting with the reference group*

In this meeting my present title of the thesis and my final research questions were in place. I presented how I intended to find out more about experiential learning in the Tofte organisation and how the learning arenas could be means for that. I also argued for the necessity for operators to develop "knowing why" knowledge. I reported about possibilities for improvement of Operations workshops, and I presented the co-generative learning model (Elden and Levin, 1991), and how this model could be used as a frame in explaining, e.g.



Operations workshops. This final meeting served as a confirmation of the relevance of my research questions and that my attempts of reporting my findings in order to improve the arenas were welcomed.

### 5.2.6 Working as shift manager

In this period I have not been active as a researcher. However, as I had to make several changes on a thesis draft from autumn 2000 and make certain changes in the analysis chapter, I have relected much on the thesis in this period. I have experienced benefits with Tofte's learning models and I have experienced shortcomings and problems. During these three years I have also been a part of a shift management training program (cf. Chapter 7.3) and have used the possibility to test theories and argue for the direction of work that Tofte has chosen with Operator training and Operations workshops. At the completion of this thesis, I will be engaged in a productivity program for one year and have by then again distance to the field.

### **Summary**

In this section I have given a broad overview of my various interactions with the Tofte organisation, and also types and extent of data in order to learn about my research questions. As I have been inspired by action research methods, I will in the next section discuss how this influenced my empirical work.

### **5.3 My participant role**

During the research period I have had different roles and tasks in the organisation. In the first period this was not an issue, but when I returned to Tofte in 1994, I was regarded as part of management. At a seminar in 1995 I became fully aware of the dilemma when shop floor workers and management were split in order to discuss different themes, and I out of old habit found it natural to follow the management group. Later that night I asked a process operator of her opinion and she had appreciated if I had joined their group. Thus this experience made me aware that I easily could be regarded as being a part of management with the limitations this might have given in, e.g. interview situations at Tofte. I was glad to learn this at an early stage in the research work.

When I had the leave from the INPRO-project in order to evaluate the Employeeship project, I also regarded myself as “external” in the organisation as I had no line responsibility and only formally reported to the project leader. But also here I was by some operators regarded as part of the management and being responsible for the project and the way some meant it turned out. With my educational background and history in the plant, I understood why I was regarded as part of the management.

I have participated in learning arenas like Operations workshops and in Operator training meetings. I was however not the one who took initiatives to the arenas. But I was a participating observer as I wanted to learn what took place in the arena and to promote the development of them. In line with my values and how I wanted to participate in the development of the plant, I also used the last reference group meetings to promote the emerging learning arenas as tools that needed top managerial support in order to be further developed.

The rather vague links to AR are my playing back of theories and interest in making a change as I believed in what I regarded as learning arenas and the possibilities for process operators to participate in development of the plant. My empirical research has benefited from this in the sense that I have been more active in the arenas as I have tried to promote and support them. I have learned more by being active than being a passive observer.

When this is not an action research project, can these interventions meet critique as empirical methods? Based on a positivist paradigm, it clearly will. But I deny the fact that a researcher in an organisation does not make any impact. If my interventions have been of any help to promote change, I regard that as positive. If other organisations will consider the theories from learning arenas from Tofte, their context will be quite different. But they might as well have “a change agent” in their organisation to promote change. I will therefore not regard my interventions as “problematic” regarding empirical research.

In the final section I will argue for the trustworthiness of my research.

## 5.4 The claim for validity

A key challenge in any social research centres on claims about the trustworthiness of the results. *“How can an inquirer persuade his or her audiences (including self) that the findings of the inquiry are worth paying attention to, worth taking into account”* (Guba and Lincoln, 1985:290). Within the conventional (or positivist) paradigm, the criteria of internal validity, external validity, reliability, and objectivity are used as a means for judging the research quality. This paradigm assumes that reality exists “out there” independently from human beings’ social action and interaction, and that “truth” can be demonstrated by means of generalisations and cause-effect relationships. The criteria for judging research within this conventional scientific paradigm further assumes that data is “found” and not produced in the encounter between the inquirer and subject of inquiry (Øyum, 1999:94).

Guba and Lincoln (1985) discuss the trustworthiness of qualitative research in relation to the conventional scientific criteria of internal validity, reliability, and objectivity. Instead they suggest credibility, transferability, dependability, and confirmability as equivalent terms to these criteria. Credibility is seen in relation to truth value, transferability to applicability, dependability to consistency, and confirmability to neutrality of the research results.

In order to ensure credibility in qualitative research, Guba and Lincoln suggest five techniques:

1. activities in the field that increase the probability of high credibility (prolonged engagement, persistent observation and triangulation)
2. peer debriefing
3. negative case analysis
4. referential adequacy
5. members checks

They see a “thick description” of the research results to ensure transferability, and suggest audits to establish dependability and confirmability. In addition they regard the use of reflexive journal, a diary research log reported to on day-to-day basis, to be a technique that covers all four criteria mentioned for trustworthiness (Husemoen, 1997).

I will focus on the techniques of prolonged engagement, persistent observation, triangulation, peer debriefing, member checking, and reflective journal in order to discuss the validity of my research results. I will also regard transferability and finally workability (Greenwood and Levin, 1998).

#### 5.4.1 Prolonged engagement

Guba and Lincoln (1985) suggest prolonged engagement as a means to establish credibility through spending sufficient time in the research setting in order to learn and understand the context, minimise distortions, and build trust.

I have earlier in this chapter described six periods that all together have given me opportunities to build trust and enabled me to collect rich amounts of data (I chose to skip project participation as the third main learning arena). My first period (1988 – 91) gave me much historical context and also an understanding and knowledge of the production processes that is necessary for a researcher to understand, in order to have credibility and insight when proposing and analysing socio-technical changes. This prolonged engagement has also given me time to report how the learning arenas have developed at Tofte and how these have affected the organisation in a period of six years. In particular the last unintended period has strengthen my belief in this way of working and on how the learning arenas should be improved.

My engagement in the Employeeship project also taught me how top management and other groups handled a big organisational development effort. As a researcher in this period I had access to the interesting arenas where decisions regarding organisational development were taken and I also wrote all the minute of meeting and summary reports from these events.

Due to my prolonged stay at Tofte, longer than most researchers for practical reasons can have, and my many and various interactions with the organisation, I will argue that I have provided a prolonged engagement.

#### 5.4.2 Persistent observation

Guba and Lincoln (1985) suggest persistent observation in order to sort out irrelevancies and ascertain the salient factors of the research context. It provides in-depth knowledge of those characteristics and elements in the situation that are the most relevant to the problem or issue being studied. As a part of the INPRO design, we started the first autumn sorting out research topics and questions. In the summer of 1995 I mapped information and communication in the production department in order to refine my research questions and what was regarded as important matters to improve (see Chapter 5.2.3). I had, however, problems at that time with how to interact with the organisation and to further refine questions that this far only were topics rather than specific questions. In 1996 I was approved to evaluate the Employeeship project and at the same time be a secretary in the educational council. It took me a long time and this was sometimes a frustrating period, figuring out how events in the Employeeship project could be combined with my own research. I studied my field notes and read about knowledge in operations. Solutions finally emerged in regarding events at Tofte as learning arenas, and in 1997 and the beginning of 1998 my questions focused on learning arenas as tools and possibilities at Tofte. By this clarification I could concentrate on learning more about these arenas and their impact at Tofte. Since I had an office at Tofte, I still had access to the research field and I could now be more specific in my further investigations.

#### 5.4.3 Triangulation

I employed triangulation in order to improve the probability that my findings and interpretations would be credible. By triangulation Patton (1990) means the combination of different methodologies in the study of the same phenomena. I studied documents, made structured and unstructured interviews, participated in meetings both as an official member in the Employeeship period, and also to a varying degree as an active observer in meetings that I during my research period have called learning arenas. I have also regarded it as important to provide feedback on my findings. In the Employeeship evaluation report from September 1997, I gave the identified learning arenas a central position, and in November the same year I was involved in the design of a follow up conference where the learning arenas also was regarded as tools to be further developed and used.

I had, during my long stay at Tofte, access to all parts of the organisation. I interviewed operators taking part in the learning arenas, and I also had much formal and informal contact with the members in the Operator training council and could thereby exchange ideas and get feed back on my early theories. In my reference group I could test out and verify direction of my research and my theories on learning.

#### 5.4.4 Peer debriefing

Peer debriefing was in fact an important factor in the INPRO design. As participant in the INPRO research and PhD program, I profited from a series of meetings designed for testing out and developing research questions, theory building, and interpreting the results of every INPRO candidate. We were a total of 9 PhD candidates from three different departments at the Norwegian University of Science and Technology and five senior researchers and professors gathered in the research group. During the programme each candidate presented their research problem and findings to the group. We set aside special days and weekend seminars to give proper feedback. The quality of the feedback was dependent on how well prepared and how well formulated the research topics were. Prior to these meetings we exchanged documents in order to meet prepared. These meetings were of major importance to me as they “forced” me to concentrate on the research questions and I got constructive feedback on which direction to choose. These meetings also had the objective to develop an “INPRO perspective” as part of the work, i.e., to integrate perspectives of the other disciplines in the programme and take a step outside our own scientific community-of-practice. At one such meeting I used the concept “process understanding” without defining it. We then had a brain storming session that gave me ideas to further elaborate the concept.

I also could benefit from discussing my research topics with an engineer with the same background and many of the same interests as mine while I stayed full time at Tofte in the Employeeship period. This contact to some degree reduced the disadvantage of not having the daily contact with research fellows.

#### 5.4.5 Members check

Guba and Lincoln argue that members' check is the most important technique in establishing credibility.

*“The member check whereby data, analytical categories, interpretations and conclusions are tested with members of those stake holding groups from whom the data were originally collected, is the most crucial technique for establishing credibility”.*

During my research period I have had five formal meetings with my reference group at Tofte. Here I reported my findings and confirmed that my research topics were relevant and of interest to Tofte. In the fifth and final meeting I also presented the cogenerative learning model (Greenwood and Levin, 1998) as a theoretical framework for understanding and explaining a learning arena.

Another important arena for discussing my research was the educational council where the educational responsible operators, the co-ordinator, and the process engineers met. In this arena my theories on the importance of “knowing why” in experiential learning, and the definition of “process understanding” were confirmed. I also tested the validity of Perby's (1995) findings and conclusions since I have used this as a central source in the theoretical part of this thesis.

In operations workshops and to the process engineers in charge of such workshops I argued for an improved design on following up as I had learnt at Tofte that this was essential to help providing lasting improvements from the workshops. These dialogues and confirmations on my findings were essential in the final theory building.

#### 5.4.6 Use of reflexive journal

Another technique for establishing trustworthiness outlined by Lincoln and Guba, is the reflexive journal. Through my work I took notes every day of observations, experiences, and early theories from my field work. By the end I had 160 A4 pages with various notes. This diary later on served as a chronological order of various events, the tables in this chapter are examples of this. In the final writing of this thesis I also used the dairy in order to categorise

events from the three identified learning arenas (later on reduced to two arenas). This technique I regard as a necessity in order to make sense out of a wide variety of data.

#### 5.4.7 Transferability

Greenwood and Levin (1998) argue that AR developed knowledge can be valuable in contexts other than those where it is developed, but they reject the notion that the transferability of knowledge from one location to another is achieved by abstract generalisations about that knowledge. Transferring knowledge from one context to another relies on understanding the contextual factors in the situation where the inquiry took place, judging the new context where the knowledge is supposed to be applied, and making a critical assessment of whether the two contexts have sufficient processes in common to make it worthwhile to link them. This has not been an AR project, but demands to transferability from AR can be used on empirical research as well. Guba and Lincoln (1985:316) outline “thick description” as a technique to establish transferability of results. They argue that qualitative researchers can only “*provide the thick description necessary to enable someone interested in making a transfer to reach a conclusion on whether transfer can be contemplated as a possibility*”. I have provided tables of my interactions so that the reader can to some extent follow what I have done. I have also included an analysis of the Tofte organisation (Chapter 2) in order to provide the reader with a better understanding of the context from which the theories in this thesis are constructed. The two methods on learning were in use at Peterson Linerboard Moss, and Tofte has developed them in their own context.

#### 5.4.8 Workability and concluding remarks

As I have been inspired by action research, I will finally use workability as a means to discuss the trustworthiness of this thesis. The results of AR must be tangible in the sense that participants can figure out whether the solutions they have developed actually resolves the problem they set themselves. Workability means whether or not a solution resolves the initial problem. The focus on the inquiry is determined by what the participants consider important (Greenwood & Levin, 1998). In this chapter I have shown how I worked with the research questions and got these confirmed in the Tofte organisation as matters of importance to treat. I report the answers to the research question in Chapter 7. The theories or answers to the questions are discussed throughout the research period with those directly involved, and my



findings are thereby confirmed in parallel with helping the production organisation to find educational tools that at the same time directly involve process operators as main contributors as well as users. In 2002 Operator training and Operations workshops have got more managerial concentration. Thus Tofte will intensify the use of these means in order to improve “knowing why” and thus better variance control.

Based on the presentation and discussions in this chapter I will claim that my findings are trustworthy. Especially prolonged engagement and persistent observations have been important in this sense. But also my playing back of research questions and emerging theories have been important to make the thesis trustworthy.

In the next chapter I describe the two learning cases before I answer the research questions in Chapter 7.

## CHAPTER 6

### NEW ARENAS FOR LEARNING AT TOFTE

#### 6.1 Introduction

I have discussed concepts like learning arenas and communities-of-practice and I have identified the control rooms in a plant as the main learning arenas - where new knowledge is to be tested and implemented into new operational practice by the process operators. A challenge given the constraints that continuous shift work gives, is to implement learning in combination with working. In this Chapter I will treat how this challenge has been met at Tofte by presenting two central training initiatives that have been under development and in use since the summer of 1996. This chapter may thus be regarded as an extension of the chronological story about Tofte in Chapter 2. The two cases that will be discussed are:

1. Operator training (OT)<sup>50</sup>- Educational material development and training developed by and for process operators.
2. Operations workshops (OW) – Examples on problem-based learning.

This order is chosen because educational material development and training (OT) can be regarded as provision of “basic” operational knowledge on which problem based experiential learning will be built. The point of each of these learning initiatives is to enhance the capabilities of the staff involved in production to keep the plant under better control and thus produce more cost-efficiently, and in a more environmental-friendly and safe manner. A common denominator for these learning attempts is that at least parts of them are taking place at a level above that of one shift in one control room. This is a core learning issue that I will return to in the analysis of the two cases.

---

<sup>50</sup> At Tofte Operator training is called “Med-Opp”. Norwegian for “Medarbeider basert Opplæring”. -Employee based education.

## 6.2 Operator training

### 6.2.1 Background

I have, in the description and analysis of “B-91” and “LOOK 92” (Chapter 2), described a problematic situation regarding operators’ basic training at Tofte. Most process operators were unsatisfied with the then situation, which can be described with the following statement by an operator:

*“I was asked to go to the boiler house and learn more about I in order to be able to rotate between two jobs, but where should I start, and what should I look for?”.*

Both the apprentices, “§20”-candidates, and operators learning new tasks followed the “master-apprentice” way of learning while working. The benefit with this way of learning is the combination of theory and practice and thus taking leverage for the tacit knowing in operation. However, this model is very dependent upon “the master”-operator and the learning environment in the control room. Could the master, for example, offer logical explanation to chemical reactions and dynamics in given operations? And could he know that all critical aspects were covered during the training period? In “Tofte language” this practice was termed “quack-quack”<sup>51</sup> -education.

As “LOOK 92”, as seen from the production department, had failed, and managers hesitated to use resources in order to conduct the plan, any new initiative would have to follow a different plan. The organisational manager reported an initiative at a Norske Skog newspaper mill, where process operators had successfully organised, developed, and conducted practical training for their colleges to the production manager. In February 1996 prior to the start up of the “Employeeship” project on Tofte, the production manager stated that he wanted process operators at Tofte to develop and conduct training as well. At that time, there were no concrete plans as to how to organise it. Being a former employee at the other sulphate pulp mill in Norway, Peterson Linerboard Moss (PLM), and also living in Moss, the production manager was in contact with persons that knew how operator education was performed at that mill. The production manager then gave a well experienced operator the mission to establish

---

<sup>51</sup> The sound from a duck. -meaning one duck blindly following its mother.

closer contact with PLM and learn more about their model, not least of their experience from use.

### 6.2.2 The initial contact and experiences from Peterson Linerboard Moss (PLM)

The first information meeting was held at Tofte in September 1996 with a delegation from Peterson Linerboard Moss (PLM) with different stakeholders, including all of the operators with responsibility for education/training. From Tofte: process engineers, shift managers, four operators, representatives from the operator's trade union, from the organisation and personell department, and myself (20 persons). The meeting began with what the initiating operator at PLM called the “fairytale” about operator education at PLM. He was and still is an operator at the mill. Back in 1989 he was very dissatisfied with what he regarded as lack of systematic operator education. The situation then was not unlike that of Tofte in 1996.

Peterson Linerboard Moss stated 5 goals for their educational programme:

1. Systematic training and education of apprentices and newly employed.
2. Offer more systematic education for operators who want to learn new departments.
3. Refresh and update the knowledge of those who operate the departments on a day-to-day basis.
4. Promote a standardised way of operating and training on each shift.
5. Promote discussion related to production questions among the operators.

These points were later on adopted at Tofte as well. After the introduction we were split into groups to discuss the experiences of the Peterson operators and process engineers. In the plenary discussion afterwards, it was decided to try to adopt the model for use at Tofte. PLM was eager to share their model, and not least their experiences of the development of the model since 1990, with Tofte and other plants as well (not necessarily pulp mills).

### 6.2.3 Experiences and results from development and use at Peterson Linerboard Moss

Since the PLM was proud of their model and wanted to share it with Tofte, one might expect that they also had some results that could be attributed to the model. I asked if they could trace any improvements in production due to the use of this model.

The answer they gave was that environmental emissions were drastically reduced without further investment. This result seems to demonstrate better process control due to better operational knowledge and practice and thus better utilisation of wood and chemicals. At the level of personell, experienced operators in charge of educating a new apprentice or operator uncovered holes in their own knowledge. They were simply not able to answer some production-related questions they were supposed to know the answer to.

The operators that have organised the educational material and developed questions and answer solutions had all experienced personal growth and were motivated to learn more. Other results were more congruent practice between shifts, a broader professional environment in the control rooms and more discussion of production-related questions and thus increased learning at work. A result from this would be shared learning and the experienced operator thereby also updates his/her knowledge. After the introduction of this way of performing operators' basic training, nobody at Peterson Linerboard Moss had failed at the official trade certificate examination. The operator responsible for educational in the paper machines department told me the following story:

*“You learn a lot yourself. Without an educational program, you tend to teach the topics you understand and neglect parts that you are uncertain about. It is also important to regard the educational phases as theory which the other production operators should learn in order to better understand connections and to get a holistic perspective of the plant.”*

Another operator told that they discussed production related questions in the control room during spare time. They formulated questions and discussed solutions, and all of a sudden the working week was finished. The operator from the unbleached department reported fewer unplanned stops in the plant, and the operator at PLM who had developed the model had no problems with admitting that he had to finish the development of the educational phases before he really felt he understood the vaporisation plant.

#### 6.2.4 How Tofte adopted the education model

Shortly after the initial meeting, the production manager and the operator's trade union leader agreed to adopt the Peterson model. All the main principles could be transferred from Peterson Moss to Tofte. This included entrusting the operators with responsibility for and the organisation of educational material from departments into phases. The production manager then made a draft of the model to be used on Tofte. This draft was discussed in a "LOOK-92" steering committee meeting and it was decided to go for the "Moss-model". Following the recommendations of the production manager, the Tofte mill was divided into 8 main departments including the laboratory with one operator responsible for the educational in each. The 8 fields reflect the geographical layout of the plant and the control room structure. Operators from each production department were encouraged to apply to be an operator responsible for educational (ORE). Within six weeks all seven OREs were ready to start. Five had applied voluntarily and two had to be convinced by a former operator who now would become the co-ordinator. A few weeks later, the shift- laboratory also was included as a learning department.

Four weeks after the initial meeting at Tofte, Peterson Moss had one of their four yearly educational committee meetings, to which a delegation from Tofte was invited in order to learn how such a meeting was conducted and to learn more about the experiences at PLM. The delegation comprised the co-ordinator, two operators interested in being responsible for education, and myself. In addition to our experiences from that day, the co-ordinator was given both paper copies and floppy disks from phases that were developed at PLM. She was also given promises of more copies whenever needed.

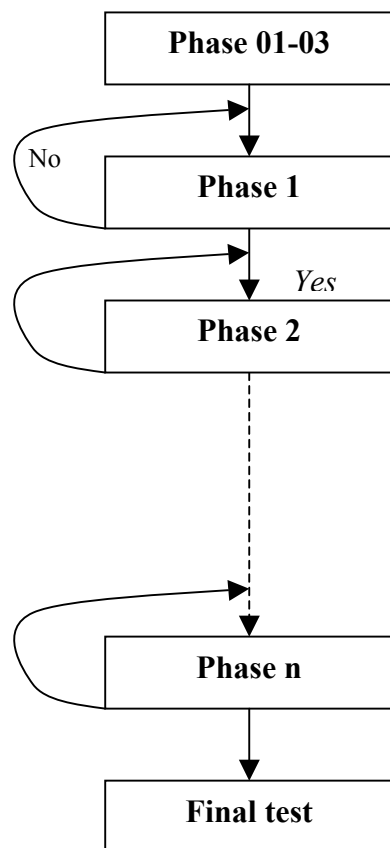
The OREs met as an educational committee which also included the process engineers, the co-ordinator, one shift manager and the manager of educational affairs. At these meetings the OREs discussed matters of shared interest, e.g., sharing of common phases such as handling of controlling systems and health, safety and environment (HSE) and the idea of integrating HSE in each phase, and what problems had occurred. The committee initially met every second month or as often as the members required.

The committee has a leader and secretary which will change each year. The operators wanted to have the leader the first year and also got the leader the second year. The committee reports

to a central educational committee, which until 1997 was the LOOK steering committee with members from the top level group, and the operators' trade union. Whenever there is a need to prioritise between candidates, the following order was agreed upon: 1) apprentices, 2) §20-candidates, and 3) operators learning a new department.

### 6.3.5 Structure of an educational program

Each sub department (see row 2 in Table 6.1) is and will be divided into phases. Each ORE decides how many phases there will be to cover each department. There may thus be a number of learning programmes related to each ORE. The number of programmes is decided by the salary system at Tofte that give one additional salary step for each sub department an operator can master.



**Figure 6.1** The phase structure in an educational programme

The programme is based on the available material at the plant and not least the knowledge and skills of more experienced operators. The programme is divided in two parts –one general and one related to the specific department. The general part consists of three phases: a general phase related to Tofte and Södra Cell, one regarding health, safety and environment, and the third regarding rules and routines related to production. (Phase 01-03, see Figure 6.1).

Each phase contains an instruction part, a section with questions and a written/oral phase test. The instruction part tells where to look for relevant information and what to do in order to learn what is covered in the phase.

The questions relate to central aspects regarding all parts of operations within the phase. These will be a assist the candidate to develop a deep and correct understanding. The questions will thus serve as internal personnel control. If the answers in the oral or written test are not satisfactory, the candidate will be asked by the ORE to study more before he/she tries again. For each phase, it is made a solution proposal. This will be given after a test is passed and will serve as a reference for later repetitions. After all the phase tests are passed and practical training such as start and stop in the learning department is performed, there will be a final test. At PLM this test is said by the founder of the model to be approximately four times as difficult to pass as the trade certificate examination. Both the ORE and the process engineer will be present when the candidate explains from flow sheets, shows practical field and equipment knowledge and answers questions. After the final test, if any doubt remains, the ORE and process engineer will discuss the matter with the shift manager to see if further study is required. When the candidate has passed the test, the shift manager may formally promote the operator to a new position (and also a higher salary grade).

#### 6.2.6. Development at Tofte three and a half year after the introduction of Operator training

The development of phases in the different departments and number of operators working with the phases gives a good indication of the degree of success so far and also of the difficulties experienced. The progress so far is shown in Table 6.1.



**Table 6.1 Organisation of learning departments and progress in development of phases, and of candidates (per April 2000)**

	(Sub) Departments	No. of phases	No. of Finished phases <sup>52</sup>	Operators in progress at phase no. PT: passed final test TF: failed at final test
1	Wood	8	3	
2	Unbleached pulp <sup>53</sup> <ul style="list-style-type: none"> <li>• Chip continuous digester</li> <li>• Pin chip continuous digester</li> <li>• Pulp screening and washing</li> </ul>	14 9 8	C 0 1	1, 2, 2, 3, 3, 7, 9, 12, 14, 2 PT  2 PT
3	Bleached pulp <ul style="list-style-type: none"> <li>• Main bleaching plant</li> <li>• Bleaching chemicals preparation</li> <li>• Oxygen pre-bleaching plant</li> </ul>	11 6 6	C 6 0	1, 1, 1, 3, 8, 9, 5 PT  1, 2
4	Drying machines <ul style="list-style-type: none"> <li>• Field</li> <li>• Drying machines 1 and 2 (capacity 210 ADT/d)</li> <li>• Drying machine 3 (1100 ADT/d)</li> </ul>	6 11 11	5 C C	3 1, 11 1, 1, PT
5	Vaporisation and causticizing <ul style="list-style-type: none"> <li>• Vaporisation</li> <li>• Pine oil department</li> <li>• Causticizing / Lime kiln</li> <li>• Odorous gases destruction</li> </ul>	7 3 15 4	C 0 15 4	4, 4, 6, C  9, C
6	Recovery department <ul style="list-style-type: none"> <li>• Recovery boiler with vapour and condensation treatment and distribution</li> <li>• Steam turbine and generator (40 MW) and compressed air</li> </ul>	14 0	12 0	
7	Boiler house <ul style="list-style-type: none"> <li>• Process water purification plant</li> <li>• Bark boiler, oil boiler, steam turbine and generator (10 MW)</li> </ul>	3 3	2 1	
8	Shift laboratory <ul style="list-style-type: none"> <li>• Pulp grades and chemical analyses</li> <li>• Final product control</li> </ul>	2 1	2 1	

<sup>52</sup> This number does not take leverage of phases that are partly finished. The total situation will thereby be a bit better. C means complete phases in department.

<sup>53</sup> The organisation of phases is changed as each phase became too big. It is also changed due to natural progress with first learning the field tasks, having a phase test and then progress with control room tasks. Reported progress is according to old organisation of the material.

The table shows a high level of variation in degree of progress. The operators responsible for the education (OREs) have a central position in OT. Their abilities in structuring educational material into phases and to write questions and answer solutions and their motivation level when doing this, has been detrimental to progress. This, however, does not give a complete explanation. The wet pulp department was well documented, with drawings and routines and procedures according to the ISO-system. At the drying machines and not least in the wood department, lack of reference material has slowed down the progress. In the boiler house, a conflict made the ORE drop out early and it took over one year to find a replacement (the replacement never produced anything written). At the recovery boiler, the original ORE got hurt (while skiing) and had to stop acting as an ORE. The OREs are also often active in other arenas as well. The OREs at the recovery boiler and at drying machine no. 3 were both active in the change of process control systems as they wanted to ensure that the monitor representations were pedagogically sound and suitable for usage in the OT phases.

In the three departments which displayed most progress, there has been a co-operation on OREs' shift, and three more operators have been included in development of the phases. Even though attempts have been made, implementation of these tasks has proven difficult on other shifts.

It was a presumed/ hoped by both the OREs and production management that as much of the material as possible would be made within normal working hours. However, none of the OREs found this possible. It takes too much attention away from the operators' work and there is not enough redundancy (people) to free an ORE to make material. They have therefore not been freed from ordinary shift work to develop the material. The "Disposable" weeks are used to cover up for absenteeism. At Tofte, a salary agreement was made giving the operators double hourly pay for working at home in order to develop material. They were also each equipped with a PC at home. The control of worked hours is reported to the coordinator. (In comparison, at Moss approximately half of the development work has been done during normal working hours).

At an educational committee meeting in 1998, it was proposed to offer two of the OREs to work daytime for ca. 1 month in order to give them a chance to progress. If that did not help after two and a half years of development, then it was suggested that others try.

In an extended educational committee in November 1997 when most programs still were incomplete, all shift managers were present as well as the production manager in addition to all educational responsible operators and process engineers. Here it was decided that each ORE should make a final test no matter of progress in phases development. Shift management had, by then, a shared basis in order to accept an operator into a new position in a control room.

So far in this chapter, I have given background for a new educational structure at Tofte. I will now discuss how Operator training can be regarded as learning arenas.

### 6.2.7 Operator training as learning arenas

In this section I will discuss in what ways Operator training can be regarded as a learning arena as discussed in Chapter 4.

The OT model structures learning to take place within three different main arenas:

- 1) In the educational council
- 2) In the development and maintenance of the phases and
- 3) When an apprentice or operator follows the phases in the control room involving the rest of the control room workers

#### **The educational committee**

This arena is an important meeting place for the OREs where they report their own progress (or reasons for lack of such) and also about progress made of candidates (see Table 6.1). In this arena, operators from all control rooms and the shift laboratory meet the process engineers and a shift manager. They meet on a regular basis, approximately every second month or when there is a need.

The committee has also served as an arena where experiences can be shared and where various problems are reported and discussed. Phases of general character such as the first 3 common phases, HSE and process control systems, in general have been exchanged wherever possible, thus repetition of work has been avoided. In one meeting the group discussed the

cost-saving potential of the co-ordination of operations so that more operators follow the same practice. The group of experienced operators thus confirmed one of Tofte's main process control challenges. It was stated that, for example, chemicals are spilled due to lack of knowledge. And further that

*“some operators have learned certain control valve positions and as long as operation is free from deviations, nothing happens.”*

These operators may have a limited ability to predict what is going to happen at the plant. The operators in the committee also discussed the issue that some of their operator colleagues are promoted too early (one operator had been accepted in a new position without being able to pass the test from phase 1). Such topics are traditionally of managerial concern, but here these are discussed at the operator level. What is of interest here is that operators raise these issues and that they have an arena in which to meet and discuss common concerns and also address them directly, as process engineers are present as well (normally) as a shift manager and the assistant production manager. They are also concerned about lack of progress for some operators. Thus, this group of operators desires more support from the shift management for those who are not progressing as well as is expected.

The educational committee, as a learning arena, serves to align educational practice and direction in the entire plant and may thus be regarded as organisational learning. Process understanding as such is not a topic in this arena. But since experienced and motivated operators are gathered from all departments, the arena is well placed for the discussion of cross sectional topics.

### **The development of phases**

In this arena the ORE meets the department's process engineer. He/she will also meet the operators from other shifts as they follow the phase programme, and the rest of the OREs' own shift that may assist in the development and maintenance of the programme. Whereas the ORE organises educational material into phases and formulates the questions and solution suggestions, the process engineer's main task will be to discuss the solution suggestions and thus assure the quality of the proposed explanations. The operator with his/her local theories can thus meet the engineer with more general models and offer a new shared explanation of

events taking place in production. In doing this, the process engineer also has the possibility for professional development regarding local theories:

*“We are “forced” to learn by accepting different phases and by having an active part in the final phase test.”*

Such local theories are most often necessary for a process engineer when suggesting optimisation initiatives. They thus follow the co-generative learning model (Greenwood and Levin, 1998).

Undoubtedly, the OREs, all of whom are well experienced, are those who really learn. The co-ordinator, an experienced operator herself, estimated that she was unable to answer 25% of the questions in the digesting department without asking or reading the answers. The learning mainly takes place when the ORE formulates questions and related solution proposals. Their mental models based on propositional, practical, and knowledge of familiarity (Göranzon, 1988) have to be made explicit. And in order to do that the ORE himself has to understand the processes and their causal inferences. In this, the OREs have to work with the spectrum of documentation and existing education material. When formulating questions based on process understanding and related solution proposals, the ORE makes his own knowledge explicit and makes it possible to share the knowledge and receive feed back from the process engineer and operator colleagues. Thus the explanations offered are likely to be more correct and also more complete than those of other operators. The OREs also will reflect on their own practice. As the laboratory ORE stated:

*“I have to go deeper into things that I did not reflect upon earlier. Things I did “habitually”. Now I question why I do this when I write about it.”*

Writing makes the ERO reflect on action and in action (Schön, 1983) while performing work.

As changes are made in a department due to technical modifications or new operations practice, this will be incorporated by the ORE. Phases may also be changed, enlarged or even skipped, due to experiences from use. New questions or answers originally not thought of by the ERO, are examples. Operator colleagues are also a source for modifications of questions and not least solution proposals. As different operators go through the solution proposals, they

may have other valid explanations not originally thought of by the ORE or process engineer. Though, the theories may be developed and refined by operators from different shifts (communities-of-practice), and thus be more useful.

### **The control room**

At the operators level, a control room serves as the main learning arena in a plant. The OT model is based on learning while being on shift. The operator follows his/her original shift independent of the ORE. (The chance to have the ORE on the same shift is 1:6). The only time an operator will be in contact with the ORE, if not on the same shift, will be during the phase tests and occasionally in shift changes. The rest of the time he/she will have to rely on the educational material and colleagues (including process engineers and shift management). All the questions and related suggestions for solutions have been checked out in a dialogue between the ORE and the process engineer in the department. The apprentice or operator is by this more likely to get a more correct model of what is taking place in terms of chemical and physical transformations and learn this correctly the first time. As one operator said:

*“Until now there has been a high level of difference, depending upon who you learn from”.*

Since the education is no longer so “person dependant”, more operators may have an apprentice or operator under education on their shift. Until now only a few selected operators have been following up apprentices. This creates a potential for learning in more shifts. The OT model will lead to more learning in a control room, the more the OT candidate cooperates with the other more or less experienced operators in that control room.

In the co-generated model (Figure 4.5), the ORE will serve as “the outsider” whereas the candidates will be “the insiders”. The process engineer will also be regarded as an “outsider” in the final phase test. In their dialogue, new theories are likely to be made.

At Tofte normally only apprentices will be additional staff on shift. That means that § 20-candidates and those who want to learn more departments within a control room have to do that in parallel with ordinary operator tasks. Taking into account that shift work can be physical demanding, there still are more quiet periods that undoubtedly can be utilised for learning. The learner will follow the phases and answer questions. He/she is encouraged to use the other operators in the control room as sources of knowledge by the ORE and the shift

managers. The learner must also be allowed to test new theories. This may safely be done when the more experienced operator is available to assist as well as cover the OT candidates' original tasks.

The more experienced operator must be prepared to accept that he/she may in fact have forgotten some theory or never had the opportunity to learn it. The important part is not to become defensive and feel embarrassed if he is not able, at the time, to find an appropriate answer. By having an OT candidate in the control room, professional debate is introduced and the more experienced operators have an excellent opportunity to repeat/learn local theory and discuss operation practice. As the OREs, who may be regarded as among the best operators in the plant, openly admit that they learn a lot from developing the phases, it should not be difficult for others to do the same. When rotation in the various control rooms is practised, more operators can take part in the discussions.

Both knowing why and knowing how are, to a varying degree, covered in the phases. In order to pass the phase tests, the knowing why has to be in place. The knowledge level is given by the requirement of answering all questions properly, but learning abilities are different from person to person, and progress may, for some, be slower/more difficult than expected. Some of the questions are formulated so that the candidate really has to understand what takes place in order to be allowed to move on to next phase. The theoretical parts will thus be easier for those with better theoretical education and understanding in mathematics, chemistry and physics, e.g. from a secondary technical school. OT phase tests will also uncover lack of local knowledge. One operator in a department was not accepted in the final test due to lack of some local equipment knowledge. It will also tell how fast an operator may learn and how eager he/she is. If an operator does not manage to answer questions, it is the best for him/herself, their colleagues, and also for the plant that he/she is not given more responsibility. This is in fact an argument in the health debate. An operator should not take responsibility before he/she feels secure in his/her own ability to master the various situations involved, given the economic consequences a wrong decision may give.

### **Short summary of Operator training**

I have presented the structure of Operator training at Tofte and how learning may take place in three different arenas. A major strength with this model is that it provides theories and

explanations that are developed and tested in an arena beside the single operator in the control room and thus is more generally valid before an apprentice or operator starts to learn. In the analysis (next chapter) I will go more into details on how Operator training is a means to provide process understanding and how the model fulfils requirements for learning. In the next section I will present the other main case from Tofte: Operations workshops.

## 6.3 Operations workshops

### 6.3.1 Background

The second main learning arena on Tofte I will discuss is called “Operations workshop”. The concept was introduced when Peterson Linerboard Moss visited Tofte in 1996, when the Operator Training (OT) presentation was given.

As already discussed to some degree, a process control challenge at Tofte is differences in operations between different shifts in the control rooms. A person or shift in a control room will often develop its own language, theories and practices. Many are convinced that their way of operating is the only correct one and any other theories are rejected. This is apparent in the recovery boiler department; *“One would think that there were 12 different recovery boilers”* was a comment from an operator in a neighbour department (vaporisation). She has observed the different practices through several years. (This observation was some time later confirmed by the process operators themselves at a meeting they held of the topic, Appendix 8).

One operator in the wet pulp department observed several shifts while he worked daytime:

*“I noticed distinct differences in operation practice and how to understand the given information.”* Another operator stated: *“I could ask three operators and get three different answers.”* Yet another operator tells: *“At the slurry reactor one shift could say: Do such and such and the problem is easily solved. At another shift they could state that the first theory would not work at all.”*

One operator related the different emphasis in starting and stopping the bleaching department:



*“What is of utmost importance to one operator is of minor importance to another. As a novice, who are you to believe?” She continued: “How do we learn by experiences made by others? It is not sufficient to read a report as it is difficult to get all the relevant information.” “If we are going to be better operators, we have to be open and honest and admit mistakes.”*

The forerunner to Operations workshops (OW) at Tofte were “forums” held weekly in the bleached and unbleached department, the department for drying machines, and later on, also in the chemical recovery department. The intention was to make an arena where problems regarding operations and maintenance could be resolved there and then. In the beginning, they served as a “venting arena” in order to relieve built up frustrations between operation and maintenance. However, after a year, these forums faded out as the interest from maintenance and production operators were lacking. The main reason behind this was lack of practical results and the fact that only one process operator was present at each meeting. His comments were necessarily not shared with other operators on other shifts, and plans could be changed the next week when a new operator with other problems and theories met the same daytime maintenance operators and process engineers. The structure of the arena did not take into account the differences between shifts.

There was thus a need in the Tofte organisation to arrange arenas where different shifts and the relevant daytime production organisation could meet, and thus overcome, limitations given by the shift structure. – To join the various communities-of-practice. An operator put it this way:

*“Problem solving forums which bring as many shifts as possible are needed in order to develop shared practice.”*

### 6.3.2 Structure of an Operations workshop

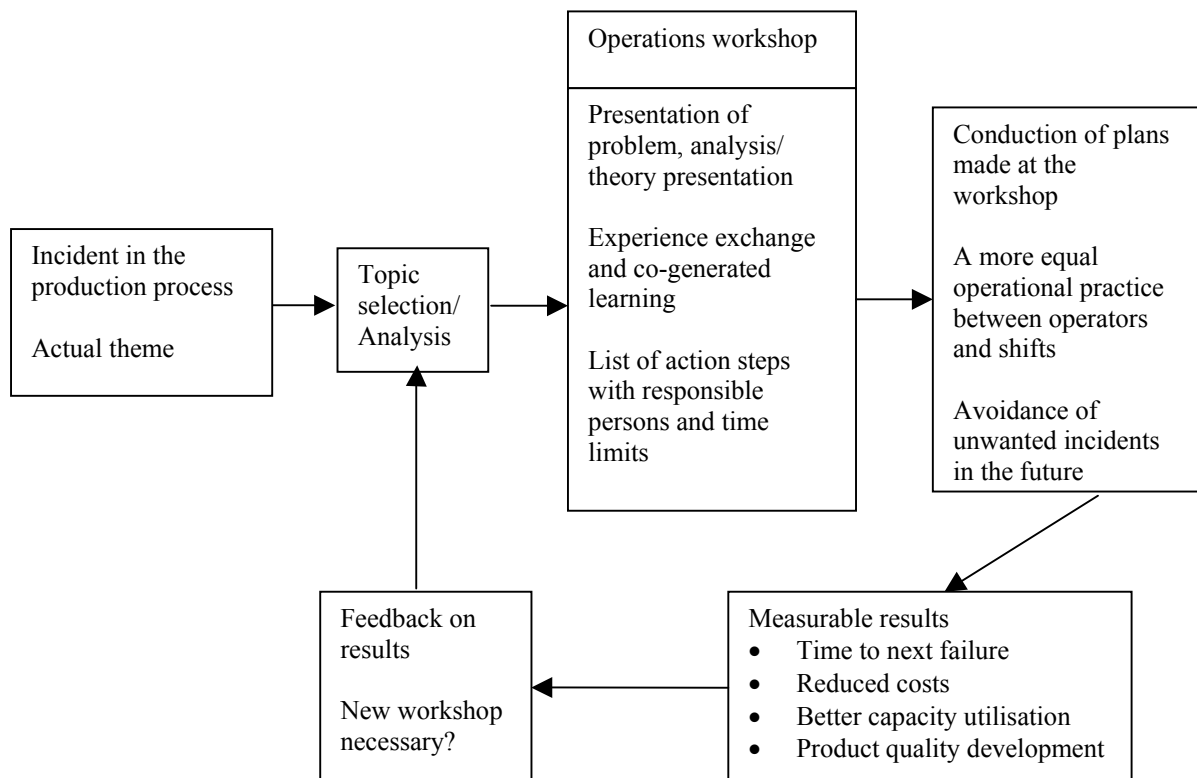
An Operations workshop can be regarded as a learning arena where relevant production personnel can meet and exchange experiences, discuss new theories and make decisions for future actions. Relevant personnel in the Tofte organisation are those directly concerned with the actual workshop topic, i.e. operators from the same department (control rooms) and from as many shifts as possible, process engineers and department management. Maintenance

personnel will also be relevant participants in most workshops and have the benefit of learning more about the processes and contribute with their theories and experiences.

A workshop can generally be divided in three main steps:

1. Preliminary work: choosing the topic and making the necessary analyses.
2. Conduction of the workshop and securing of statements and agreements.
3. Follow-up activities and feedback on results.

An operations workshop can be represented with a block diagram:



**Figure 6.2 Schematic representation of an Operations workshop**

The block diagram and the following description of a workshop structure are based on experiences drawn from 10 workshops at Tofte in 1996, 97 and 98. The background and topics of the workshops are given in Table 6.2.

**Table 6.2 Operations workshops at Tofte in 1996, 1997 and 1998**

Datum	Department	Topic	Background	Attendance Total/operators
961209	Chemical recovery	Development and use of routines and check lists	Create a useful system and shared understanding of the need for check lists	19/9
970123	Continuous digester	Reduced capacity and quality in digester	Split in digester plug	21/12
970218	Drying machine no. 3	How to avoid rupture in the pulp web	Drying machine is capacity reducing	18/11
970220	Lime kiln	How to avoid future breakdown	Breakdown of insulating bricks	10/5
970422	Boiler house	How to produce more steam from bark and less from oil	Too high oil costs	11/5
971112	Bleaching chemicals; ClO <sub>2</sub>	Safe production	Minor explosion in reactor	22/11
980223	Digester and chemical recovery	How to avoid turpentine in gas system	Temperature fluctuations and near to failure in lime kiln	10/8
980428	Bleach plant	Optimisation	Cost reductions and quality improvements	22/8
980526	Pin chip digester	Optimisation	Increase capacity utilisation and reduce kappa variations	19/10
980825	Wood department	Identify bottlenecks and find solutions	Too low capacity utilisation	16/14

The 10 workshops in Table 6.2 have, this far, been initiated by either the production manager, department managers or process engineers. The background for the workshops are episodes in

production that require knowledge and experience of all those involved in the production problem at the same time in order to improve practice. Production failures and capacity reducing episodes are the most common reasons for having a workshop, but optimisation is also an appropriate theme.

The outcome of a workshop is dependent upon all the three main steps. The first step is preparations for the workshop. In order to have a point of origin to discuss production topics, relevant production parameters often have to be analysed and systemised in order to pinpoint what the problem is. This may help to reject or confirm theories/explanations that may arise during a discussion. An OW is also a suitable occasion to bring in relevant theory related to the issue at stake.

The second step is the workshop. As the main idea at the workshop is to find shared solutions to problems, it is important to have as many attendees from different shifts as possible. Given the shift cycles on Tofte this is best accomplished by starting the workshop at 2 p.m.

Theoretically staff from 5 shifts will then be able to participate. A workshop will normally last 5 to 6 hours, and dinner is often served in the middle. The starting point means that every participant, including daytime staff, have to work overtime. But given a shift structure and the over-arching aim to join as many shifts as possible, overtime is unavoidable.

At the workshop, an introduction is held where topics and background are presented, as well as work done prior to the workshop. How the workshop is further organised depends upon the problems under discussion. Analyses and/or specific theory may be presented. The “problems” are sometimes clear, but a plenary round (brain storming) may be required to clarify more specific questions to be answered during the workshop.

Group activities are regarded as a key factor in order to activate all participants and make it “safer” to bring in individual’s experiences and explanations. The groups are organised as mix of shifts and daytime personnel (management and maintenance staff). In a workshop, the knowledge and experiences from daily operations from as many operators as possible is regarded as necessary in order to develop the mill. Some special episode of importance may have happened during just one shift or have been recognised as a phenomenon by just one operator. Such experiences might be of value, and thus need to be captured. The proposals from the groups are presented and discussed in plenary and a shared strategy for further action

has to be agreed upon. What is of special importance is to make a task list of planned actions including what to do, when to do it and who is responsible. Such a task list is necessary in order to know what specific parameters that are to be followed up and thus see if any learning actually has been taking place.

As a part of the third step, a thorough report from the workshop has to be made. When tasks are related to shared practice in order to evaluate if proposals give desired effects, it is of special importance to be specific. If a task list is provided and followed up, feedback to relevant production personnel is easier to provide.

In the following I have selected two workshops that best illustrate the structure and potentials of such workshops. The remaining 8 workshops are described and analysed and are placed in Appendix 8. All 10 workshops given in Table 6.2 are, however, used as a basis for answering the research questions.

### 6.3.3 Examples on two specific workshops

Here, I will give an overview of what took place in two of the workshops, relate them to the structure or design characteristics of the workshop and try to trace some lasting results. The two chosen workshops are the ones relating to the continuous digester and to the lime kiln. These two workshops show some interesting results that can be directly related to this way of working and co-operating.

#### **The continuous digester workshop**

The production manager made an initiative to a workshop as a serious problem was experienced with the continuous pulp digester. (The digesting process is described in Chapter 2.4.2).

Tofte's continuous digester is at a maximum operated at a speed of 40 tonne/m<sup>2</sup> a day while the vendor today uses 25 as design criterion. This relatively high throughput rate at Tofte makes operation of the digester more critical to deviations in raw materials and in process parameters. While producing long fibre pulp (from spruce and pine) during the winter season when snow and ice will lead to an extra amount of vapour (and thereby liquid) during cooking the pulp, Tofte experienced severe problems with getting the wood chips through the digester

as a continuous plug flow. When the chip pile stopped somewhere in the digester (inside, it can be regarded as a hollow tube), this resulted in a split in the pile. When the chip pile loosened, these chips would get a shorter cooking period and this result in quality variations and production problems downstream with screening, washing and bleaching.

The digester operators had different theories and different practices regarding how to try to avoid and how to handle the problems. Production management had their theories, but they needed help to refine and confirm them and not least help to implement shared practice across shifts. As the department manager stated at the beginning of the meeting:

*“Theories from Employeeship have to be transformed into practice. The operators and shift management operate the plant continually. We have to learn together and solve the problems together.”*

Prior to this workshop the assistant production manager had made a historical comparison between critical and typical parameters from 12 winter days when the pulping process was stable. Based on this analysis and experiences from the operators and daytime personnel, a brainstorming session was held to find as many factors as possible that might have influence on the problem. After this, four groups worked further with discussions and solution proposals. Back in plenary, results were discussed and priorities and persons responsible for following up were agreed upon.

### **Outcome of the workshop**

In “Toftenytt”, 10 days after the workshop the production manager wrote:

*“We are pleased that the digester has been more stable and produced more than has been the case for a long time while producing long fibred pulps. The proposals based on discussions from the workshop have been tested and this looks promising.”*

Table 6.3 gives an overview of the problem and that this specific production problem was, in fact, resolved after the workshop. From the minutes of meeting, which is documentation of what took place, it is stated that the most important result is that new operation parameters have to be established and then followed up by every shift.

**Table 6.3 Loss in tonnes (unbleached pulp -digester production) due to digester instability**

		Internal stop	Capacity reduction
1996	1. half	957	2,545
	2. half	546	2,377
1977	1. half	268	2,048 <sup>54</sup>
	2. half	0	1,000
1998	1. half	0	0
	2. half	0	0
1999	1. half	0	1,644
	2. half	0	0

From the resulting list of proposals, some points were highlighted:

- A constant level of blowing and dilution factor (concurrent washing) in the bottom of the digester.
- Feed level control.
- Make a balance between blow tank and screening department to find the amount of pulp in the blow line.
- The C-shift will plan the above points in more detail.
- The difference between long- and short liquor circuit will be shown as a trend in the process control information system. (Indication of split in the chips plug).
- Avoid “shock blowing” of pulp from the digester.

The result reported in “Toftenytt” is due to the new, shared operational practice across shifts.

As an operator reported:

*"Everybody had his or her own theories. It is evident that the digester has displayed less variance after the workshop."*

<sup>54</sup> Includes January 97 before the workshop. Loss in January 97 was 1,500 tonnes.

At the workshop, it was agreed to keep the chip level in the digester at a constant level and control the feed rate in order to obtain this. The control signal should thus be transferred from the amount of blowing in the bottom to the set point of chip feed. The amount of digested chips from the bottom of the digester would then be automatically controlled as a result of the feed. The attending operators agreed to follow this strategy in order to avoid further problems. From the workshop in February 1996 and until late November 1997, such disturbances were avoided. The first two months the operators had to follow up this new control practice by manually adjusting set points until the project of reprogramming in the computer control system was completed. In November 97 the shock blowing tactic was tried again in order to try to regain level control. The operator who tried this had not been an attendant at the workshop. This event led to further instability in the digester and extensive fluctuations in the degree of cooking (measured as a kappa number). These disturbances propagated to the bleach department and further to the drying machines. The end result was off grade quality and reduced production. In the production plan for week 49-50 in 1997 the production manager wrote:

*“At the operations workshop in February, an agreement was made as to how such problems should be treated and how to best operate the digester. This is still yielding results. Find the report from the workshop and study it carefully!”*

The residence time in the digester system is at a production speed of 1,100 tonne/day about six hours. Due to this long residence time, deviations or planned adjustments take a long time to be detected and something which is most likely to occur on next shift. A new steady state has to be established in order to get results and feedback before new changes are tried out. If the operators at different shifts do not follow instructions and make their own changes based on their personal theories, they will not be able to learn from their experience because the effects can not be traced back to initial causes.

The production statistics clearly shows improvements that can be traced directly to the workshop. In addition, to better operational practice, technical modifications like better screening of chips for the digester and a new internal screen have made the system more robust. Another effect in 1997, compared with 96, is less off grade pulp. This and other effects are discussed in Chapter 7.3.2 where I discuss if changed organisational practice has led to improvements in production.



**The lime kiln workshop**

At the lime kiln workshop<sup>55</sup>, the central background problem was how to avoid or delay failure in the insulating bricks in the kiln. The rate of failures increases with stable high temperature or high temperature peaks. When this happens, insulating bricks in the rotating kiln fall into the kiln, and the kiln has to be stopped in order not to melt a hole in the metal mantel where the bricks are missing. Burnt lime has to be bought and transported from Sweden and this typically costs NOK 1,6 million each time. The total costs are therefore in the range of NOK 2,5 million. The lime kiln is fired by oil and sulphuric gases from digesters and vaporisation plant. The heat content of these gases varies and thus causes fluctuations in the temperature in the kiln. In order to avoid high temperature peaks, the energy load was reduced by 6 % and thereby the average temperature in the hot end of the lime kiln reduced from 620 to 580°C. In addition to trying to avoid failures, this gives reduced CO<sub>2</sub> emissions and a yearly cost reduction in the range of NOK 2 million.

**Table 6.4 Oil consumption in kg per tonne of pulp**

Year	1994	1995	1996	1997	1998
Oil consumption	41.19	40.33	41.20	38.47	37.08

Why had this rather simple measure not been taken before? The main concern had been the quality of the burnt lime (CaO). Would a change in the process affect the quality of the lime or disturb the down-stream process? Nobody had challenged these assumptions before. Operators wanted to be on “the safe side” and this practice went unchallenged. Analyses taken after the temperature reduction showed no decrease in quality and no disturbances have been reported in the following processes.

In the theoretical part of the workshop attention was also paid to routines and the understanding of the necessity of following these routines. One operation is to wash a filter. This operation will lead to a drop in the feed to the lime kiln. This zone with less chalk will reach the burning zone typically after 4 hours. Since there is less chalk to absorb the energy in this period due to a chemical reaction from CaCO<sub>3</sub> to CaO, the operator has to be aware and reduce the heat input (oil) accordingly during this period.

---

<sup>55</sup> The lime kiln is described in Chapter 2.4.4.

After the workshop there were agreement on how to operate the lime kiln in a more even manner. The main goal for the workshop was to increase the time until the next failure with this lower heat load. Results so far show that the number of failures after the workshop has been one in 1997 and one in 1998. With an earlier average of 3 failures a year, this measure has so far resulted in a cost reduction of NOK 7 million per year. Thus the workshop itself, and its follow up, has been successful.

During the maintenance stop in 1998, measures were taken to reduce disturbances in the gases and not least a predictive control system was installed. So far, this has controlled the lime kiln satisfactory, also during the feed drops. As one operator pointed out:

*“If I did not do anything else, I could maybe operate it as well as the automated system.”*

The gases are still a source of deviation but the automated system seems to control this satisfactorily.

#### 6.3.4 Operations workshops as learning arenas

I have described a workshop structure and how workshops are conducted. Moving from a general overview, I have provided two detailed examples (plus eight in the appendix) of what I have called Operations workshops (OW) and a final example (also in the appendix) something akin to this workshop structure as given in Figure 6.2. In this section, I intend to discuss to what degree such workshops can be regarded as a learning arena as presented in Chapter 4.3.

I will start the discussion by looking at the workshop itself as this is the core of the arena where people from various communities-of-practice meet, share experiences and develop their mental models. However, to follow Kolb's (1984) definition of learning as transformation of experience, these transformations have to be tested in everyday practice in the control rooms.

#### **The workshop**

The structure of an Operations workshop can be regarded as similar to the cogenerated learning model (Greenwood and Levin, 1998) given in Chapter 4.3. This model is

useful as a framework for understanding a workshop. In the first phase of a workshop, operators (insiders) meet the production management (outsiders) and other relevant staff in order to provide theories and explanations to clarify the problems. I have regarded each shift in a control room as a community-of-practice. The daytime organisation can also be regarded as a community-of-practice. Thus an Operations workshop is an example of a community-of-communities where learning and development can take place.

When a decision is made to arrange an Operations workshop in order to solve the problem, preparations have to be made in order to highlight the problem and to provide some general theory to help understand the problem. Experiences from Tofte have revealed that the outcome of a workshop is dependent upon how well a workshop is prepared.

Will a more refined and representative model of reality be an outcome? Operators have different mental models of the production equipment and how it works. Automated systems and transformations taking place with just a representation of measurements on a screen, demands that people have a capacity for abstract thinking. The aim of Operations workshops is to try to align differences between operators and shifts by introducing arguments that may help them to develop a more shared model. Thus an OW gives attention to what influences the problem at hand and the participants are likely to “learn why”. Explicit theory is a mean here, e.g. how  $\text{OH}^-$  and  $\text{S}^{2-}$  attach lignin and hemi-cellulose differently, why it is important to control the concentration of various chemicals in different positions in the equipment, and what the optimum values are. Such explicit theory also serves to explain what happens to the product if these values are not kept within given limits. In other workshops without “theory sessions”, a lot of explanations and examples have been provided in order to highlight the problems.

In the second phase of the workshop, strategies are formulated as to how to solve the problems and a task list of actions is provided. This task list is made in co-operation, between operators from different shifts and relevant daytime personnel. From now on “insider” testing of co-generated theories has to be made by the individual operator on each shift.

Operators in the control rooms control variances in parameters. Theories from a workshop are of no use unless they lead to the new desired practice. Production systems are big, integrated, and thus complex. Often complex theories are provided as explanations at the workshops.

Thus the theories or hypotheses need to be tested in the control rooms for a longer period of time in order to be accepted or rejected.

#### **6.4 Summary of learning arenas**

In this chapter I have presented two different kinds of learning systems at Tofte: Operator training and Operations workshops. I have provided background for the two cases as an answer to the educational challenges Tofte had in 1996 and not least to differences in operational practice between shifts. I have also discussed in what ways these two learning systems can be regarded as learning arenas and briefly the kind of learning that can take place in each arena.

In the next chapter I will provide answers to the research questions from chapter 4 based on the theory discussion and the case presentation in this chapter and thus further outline the strengths and benefits of the two learning systems related to development of process understanding.



## **CHAPTER 7**

### **ANALYSIS OF TOFTE PRACTICE**

In this chapter I will answer the research questions outlined at the end of Chapter 4. The structure of and headlines in this chapter follow the research questions. The first question is: What are the learning systems for workers in a process plant? I will relate the answer to Tofte and the learning arenas presented in Chapter 6 and analyse the kinds of learning and kinds of knowledge that are provided in these. Further in this chapter, I will analyse how the production organisation has implications for learning by discussing two different socio-technical structures. Finally, I will analyse how Tofte practice can be further improved by looking at matters that arise from the first two questions.

#### **7.1 Learning systems for workers in a process plant**

I will relate the answer to this question to the two main cases from the previous Chapter with an emphasis on how these two main arenas cover collective learning and experiential learning and thus improve more traditional systems and also how they meet the requirements for good learning systems given by Ellström (1996) and presented in Table 4.2. I will look at the first question by analysing the two main learning cases separately. Firstly, however, I will look at a traditional educational measure for contrast.

##### 7.1.1 A classroom attempt

In addition to use of learning arenas as described in Chapter 6, an attempt was made in 1998 to offer a more traditional classroom based education in the causticizing department (includes the lime kiln). This was an attempt to provide and strengthen the “knowing why” capacity by putting emphasis on equipment, systems, and chemistry. Six process operators, who are all regarded as motivated and experienced, met up in addition to six operators from maintenance functions from the same department. The arena should thus be ideal for experience exchange between the operators and also between operations and maintenance. They met weekly, generally outside the shift hours of the process operators.

However, this attempt was not, for various reasons, a success. The instructor, a chemical engineer with pedagogical training did not have any local knowledge based on production experiences to provide any discussion. Most operators also found the chemistry difficult and hard to relate to their daily practice. After 15 out of 20 lectures, the instructor and “pupils” decided to give it all up. When the instructor evaluated the course, she found that it was important to express the expectations related to the course. One main reason for the lack of success she found was that the operators, to a large degree, expected to be (passively) taught and not participate themselves. The education became too theoretical and the participants did not see how they could improve their daily operational practice even though the lectures were “Tofte specific”. It was not based on operators’ experiences from problem solving in practical situations.- It did not constitute problem based learning. The group was a good mix of process- and maintenance operators, however, as no management staff were present, and it was not discussed how suggestions for improvement should be taken care of, development of local theories did not become central. This was also due to the pupils’ expectations of being passively taught. The planning and execution of the lectures was also done by the instructor with no involvement of the operators.

This single example does not mean that any attempt to provide general theories in a classroom setting are bound to fail. Shorter courses designed to meet specific challenges can and will be an appropriate mean in given situations. This case, however, serves as one example to confirm Ellström on how learning efforts ought to be planned and performed. In 1998, the operators in the causticizing department had good experiences with Operations workshops, and their recommendation was to instead use resources on problem based workshops.

### 7.1.2 Learning types related to Operator training

Operator training at Tofte is a means to provide basic operational knowledge mainly to the process operators and apprentices. The goal is to effectively increase each operators’ “knowing why” and “knowing how” abilities and thus make the operator more able to control a given production section. As discussed in the theoretical part of this thesis, different kinds of knowledge are all important in order to be able to control a plant. These different kinds of knowledge were denoted as propositional, practical skills, and knowledge of familiarity by

Göranzon (1998). How OT covers these, as well as how OT is a means to overcome shortcomings in traditional learning systems will be looked at in the next sections.

### Collective learning in OT

I will start with an analysis of the links between collective and individual learning. I have argued that collective learning is necessary in order to align differences in operational practice between operators and between shifts. In Chapter 6, I described how learning could take place in three learning arenas and thereby be regarded as collective learning; In the educational committee, during the development of phases, and finally in the control rooms. Collective learning serves as a direction or as a frame for the individual learning.

A strength with OT is the way collective and individual learning is combined. Before 1996, learning at Tofte was, to a greater extent, occasional and had little shared direction between departments since the two local instructor positions were removed. With OT there is now a common system within the entire plant, and this system is maintained at the collective level in the educational committee learning arena. Especially during the first year of development from 1996 to 1997, this was an important arena as nobody at Tofte, at that time, had any experience with the system and how it would develop. The discussions in these meetings served as motivation for the educational responsible operators to continue their work. The collective learning in this arena was thus the development of a similar system in all departments in the plant.

Another strength at collective level is the arena where questions and solution proposals are discussed between the ORE and the process engineer in the department. This serves as an assurance that the central aspects of what is needed to be learnt will be covered. In this arena, the process engineer will be tested on his/her knowledge as well, and is, as such, a means also for the process engineer to develop new insights and better local knowledge. This provides the apprentices and operators with theories and explanations from the entire department and not just only what the “master” on his/her shift knows.

The third arena that can be regarded as collective is in the control room when the final test is taken. The ORE and process engineer will then try to uncover lack of knowledge. What can also be regarded as collective learning is the interchange between the candidate and ORE



when answers are given to questions and some of these answers are the new standard solution proposal. This is a strength of the system. But how good is it as an individual method?

### Individual learning in OT

The link to individual learning is seen when the apprentice or operators work with the phases in the control room or in the field. The master-apprentice method has a strong tradition within crafts and industry. It is the most applied method where an apprentice or novice can combine theory with practical skills. The co-ordinator of the programme is convinced that OT will contribute to increased process understanding.

*“I wished I had such a system when I learned the wet pulp department. To understand why things happen and the theories behind them. Not just how valve positions should be in relation to each other.”*

This statement is in line with the studies made by Zuboff (1988) and Perby (1995), and confirms how the local education to a large degree depended upon the “master” explanations. OT is a means to strengthen the “master-apprentice” model as theory and practice will be combined in the learners’ own tempo and not least that the master now is equipped with a better tool than his/her own individual memory. With this tool, more operators than before can be the “master” and thereby also improve their own knowledge and mental models.

At Tofte the ability to learn from experiences in a complex process plant have been identified to be a challenge. By experiences, major production failures often are meant. I have identified “knowing why” knowledge as a core component in order to learn from experiences and in order to develop process understanding as “an ability to predict what is going to happen”. Through OT theories and explanations are provided so that “knowing why” is provided. In the control rooms this is combined with “knowing how” by studying flow sheets and not least making studies of and on the production equipment in field. Knowledge of familiarity requires experience from different situations and an analysis of such situations require both “knowing why” and practical skills -“knowing how”.

One operator following the model stated:

*“I believe this will contribute to more equal practice as more operators will achieve a higher level of knowledge.”*

After having finished a phase programme and two having finished a final phase test, the three operators argued that better knowledge would lead to more equal practice between shifts. In a typical classroom setting as exemplified in this section, theory is not that easily combined with practice. With OT, the “classroom” is the control room and physical equipment in the field. Thus theory and practice is combined in a way that each candidate can adapt individually as some are more theoretically or practically minded than others.

In this system, all candidates have to cover all parts of the department that experienced operators and process engineers have decided to be necessary. They thereby also have to answer the more difficult questions that earlier would most likely not have been raised. This is a major strength with Operator training as pedagogic model.

#### *How Operator training meets requirements for learning*

How does Operator training meet the requirements for learning systems as given by Ellström and presented in Table 4.2? The first requirement is to “originate from problems and developmental needs in the plant.” At the collective level, this requirement is met since there was clearly a need in the Tofte organisation to improve educational systems and practice. The operators, not least, stated this need before 1996. At the individual level, the requirement can be combined with the second one of being based on individuals’ experiences from problem solving in practical situations. This is, to some degree, met since “problems” are presented as questions within the phases. Experiential learning as method is not covered directly within OT.

In Table 4.1 a presentation of two models was given in order to understand operators’ work and competence demands. This can be taken together with Table 4.3 that presents differences between adapting and developing directed learning. The main intention with OT is to provide thorough basic knowledge to the novice. Thus, before more experience from operating the plant in an independent position is gained, the operator will follow a more rationalistic perspective and OT will also cover adapting directed learning as a necessary basic requirement. However, as OT in the various departments is thorough and thus demands effort

to be realised, a basis is given to learn from experiences and thereby OT is also a basis for developing directed learning.

OT covers sub-departments within each control room. In each of these, OT provides knowledge on both parts and systems within the whole area. As such, OT is a tool for performing work tasks related to the whole system. OT also provides a basis for the core in process understanding: To formulate a problem, analyse its origin and how it may be solved, and further to critically judge measured values and take appropriate action. As one operator at Tofte said:

*“Those operators with the best theoretical understanding treat problems most elegantly. Where some may try and fail, others go for the correct solution more directly”.*

Benefits from “knowing why” should thus be clear. OT as learning system is a basis for further learning from being a novice in the direction of expert (Dreyfus & Dreyfus, 1986).

#### A summary of Operator training at Tofte

Tofte has, through Operator training, developed an educational model with several benefits:

- Same structure in all departments in a plant.
- A model based on phases that is individually adapted to different departments.
- All questions “force” operators/apprentices to learn what experienced operators and engineers regard as necessary.
- Phases can be developed as new experiences from production show where more focus is needed.
- Questions are directed at “knowing why” in addition to “knowing that”.
- Learning takes place at both the collective as well as individual level.
- It strengthens the master-apprentice model in the control rooms as more operators can be “the master” as collectively developed explanations are given in the solution proposals.
- It is a system that gives a basis for process understanding and thereby developing directed learning.

However as is shown in Table 6.1 the progress in making and finishing the material has been slow, although there is extensive variation between departments in this respect. Also, the content in phases has varied as some phases have become too detailed and voluminous to be realised within a reasonable time.

In this section, I have delivered arguments as to how the OT system has strengthen operators' education at Tofte, both at a collective level with a shared direction and at an individual level as it strengthens the master-apprentice model of learning in the control room. How development and the use of Operator training influences and depends upon organisation and management will be a matter for analysis in the next question. A discussion on how Operator training can become a more effective tool at Tofte is related in the third and final research question.

### 7.1.3 Learning types related to Operations workshops

Whereas Operator training is a means to provide basic operational knowledge to mainly apprentices and operators who need and want to learn a new department, what kind of systems can be offered to more experienced operators? And what kinds of systems can help other groups in a production department in their work to improve production? This is the theme in this section, where I discuss learning types related to Operations workshops. An OW is arranged with the primary purpose of improving process control and production and not as a learning measure. As learning will necessarily be an outcome (although to a varying extent), this is an example of how learning and working can be combined and integrated and not regarded as two separated tasks.

As presented in Chapter 6.3.2, a workshop can generally be divided in three main steps:

1. Preliminary work: choosing the topic and making the necessary analyses.
2. Conduction of the workshop and securing of statements and agreements.
3. Follow-up activities and feedback on results.

Figure 6.2 also provided a schematic representation of a workshop. Here I will discuss how various learning types are covered in Operations workshops given the experience from Tofte.

At Tofte 10 Operations workshops took place from December 1996 until September 1998<sup>56</sup>. The workshops were carried out in all control rooms, thus the method is copied throughout the entire production organisation. An Operations workshop is problem oriented and analyses are made in order to highlight the problem and to find solutions. This can help to better understand causes and effects and how systems are integrated with other systems. In all workshops central topics have been deviations and how these can be controlled in order to, e.g., optimise departments (bleach plant and pin chip digester), solve a pertinent problem (the digester, the lime kiln and the turpentine workshops) or cost reductions (bark boiler). Two workshops, thus far, have covered two control rooms where the topics have been discussions of how disturbances originate in one department and what the consequences will be in the department where the results of the deviations manifest themselves. But, an OW is also a means to detect variances occurring within the range of one control room. E.g., from the wet pulp control room; chip screening, digesting, pulp screening, washing, and bleaching are all controlled by three indoor and two field operators. Especially in the bleach plant workshop, where optimisation was the theme, much emphasis was placed on the need to reduce incoming variances in order to be able to optimise the bleaching result at a lower cost, i.e., reduce fluctuations in kappa values from the digesters and focus on the washing process with higher dry solid content from the screening department.

In the following I will discuss how the various learning forms will take place in different arenas. The two main arenas regarding OW are the workshop itself and the relating tasks to be handled in the control room after a workshop. I will start by looking at collective learning.

#### *Collective learning in the prephase*

The first step of a workshop is to choose a topic and the work prior to a workshop. Based on Toftes' experiences the more problem oriented the workshop is, the more likely it is to have a detectable positive result. The questions have to be precise enough in order to be answered within the frames an OW offers. So far at Tofte, the choosing of topic and preparations for the workshop have been a task for production management and process engineers. Thus, the first step of a workshop has not served as a means for collective learning between engineers and process operators. How this may benefit from a change, will be a matter of discussion when I in the last question look at how OW can be improved.

---

<sup>56</sup> In section 7.3.2. I will comment the development from 1998-2002.

### Collective learning in the workshop

The cogenerated learning model (Greenwood and Levin, 1998) is useful as a framework for understanding a workshop. In the first phase of a workshop, operators (insiders) meet the production management (outsiders) and provide theories and explanations to clarify the perceived problems. In the second phase of the workshop, theories are formulated as to how to solve the problems and a task list of actions is provided.

After the invitation to a workshop is sent to the relevant production staff, there is time to prepare solution proposals and explanations of the relevant issues. At Tofte, this has, to a minor extent, taken place. In order to achieve a shared direction and explain the issues for the workshop, general and specific theories are provided. So far at Tofte, these theories are provided from what can be regarded as management. However, in this arena motivated staff are present, and theory is used to highlight the problem at hand and not just given as theory alone, as often is the case with more general theories. This is what is often the problem with classroom teaching – to connect general theories directly with challenges at work. Such a theoretical session has taken place in most workshops. Relevant theoretical discussion has ranged from chemistry in pulp digesting and bleaching to production statistics and the state of parameters when production is in a “steady state”. Again, when the topic for the workshop is well defined, theories and explanations can be more easily directed at the problem. Also engineers’ need for propositional knowledge is met in a workshop. Problem based learning is a convenient way for this group to learn as well.

Provision of explicit knowledge from outsiders to insiders is what Nonaka and Takeuchi (1995) denote as combination. Such conversion is useful when the theories are highlighting the specific problem and the receivers know it is relevant. An OW can be regarded as a way of modelling the problem and solution proposals. Theories and explanations are thus provided in order to highlight the problem and provide the attendants with “knowing why”. The aim is to make the mental models of the problem more shared. Cannon-Bowers, Salas and Converse (1993:228) (in Nonaka & Takeuchi, 1995) define shared mental models as

*“.....knowledge structures held by members of a team that enable them to form accurate explanations and expectations for the task, and in turn, to co-ordinate their actions and adapt their behaviour to demands of the task and other team members.”*

This definition also is useful when the mental model covers a process system. Nonaka and Takeuchi, however, argue that the most important conversion form is from tacit to explicit knowledge and that this has to take place within a “field”. An Operations workshop can be regarded as such a field where operators from different shifts meet. Although they follow different practice, they use the same systems and equipment and thus have a shared background for understanding the meaning of the concepts used. One operator can thus come with examples and analogies that another operator can use in making his/her mental model better suited to explain the problem at hand and the various reasons for it. Small groups, where all participants may feel more free to exchange ideas, make good fields for tacit knowledge to surface. This is accomplished in an OW where group discussions of identified items are of major importance to arrive at explanations and solution proposals.

In a workshop the most experienced operators have to participate, they must use their knowledge of familiarity and their experience in how the process equipment and systems actually function in different situations. The more inexperienced operators will also benefit from the discussions, but their outcome will be more limited as they lack the knowledge of familiarity of similar situations. Thus the various knowledge forms are used when the topics are discussed.

After group discussions, typical workshop practice is to present provided answers and make an extraction in order to make list of tasks to be followed. The task lists will typically be a mix of operation practices, new routines to be followed and modifications of equipment. What may also be an outcome of collective learning is a shared understanding of why it is important to maintain certain equipment, as was the case in the bleach plant workshop where operators could address this directly to the leader of the instrumentation group. Here it was stated that the online measurement of residual lignin was pertinent in order to save bleaching chemicals and produce pulp with the desired brightness.

Another benefit with this way of performing work is the way new theories and explanations are cogenerated as the various communities-of-practices meet and talk. Within the various communities-of-practice there will be different views and priorities. Thus, the tasks lists that are provided as a summing up of a workshop, are likely to present best operational practice. Also, since process operators and management have decided on the content of the task list together, there does not have to be any further discussion as to what to do and why this should

be done. Thus a cogenerated understanding of the current issue, its explanations, consequences, and solutions has come into being.

Precise questions, theories, and analyses to highlight the problems help to direct discussions and increase the possibility to end with a concrete task list from the workshop. Three out of the ten workshops at Tofte have ended without such task lists. Disappointment and frustration characterised the collective learning from these sessions. This has been due to lack of interest shown as few attendants, improper preparations prior to the OW and operators and management not being able to move away from being problem oriented to being solution oriented.

The third step in the chain of a workshop is the tasks to be followed up. This will be the theme in the next session where I discuss collective learning in the control room.

#### Collective learning in the control room

If the two first steps of a workshop have been successful, the final challenge is still there: Will process control be improved? A report with theory, discussions and the task list containing who is responsible and time limits, that is as close to the workshop as possible must be provided. This acts as an aid for those present and not least for those who could not participate.

In the control room now, six shifts have to follow the same new practice. An OW with its task list has given direction as to what to do, when this is to be done and by whom. Also the reasons for changed process control practice have been discussed in a cogenerative form. This has led to modifications in equipment, such as changes in automated controllers, new set points, and new shared practice (new routines) that can be any combination of better knowledge and changed technology. An example, is the change in the control of the continuous digester. The new process control practice was first practiced in a manual mode before the control system was reprogrammed in line with the intentions formed during the workshop later on. At the lime kiln workshop, that this far has given promising results, a new advanced control system was installed one year after the workshop. But beside these two examples, a lasting change in practice in the direction of less variance between shifts is thus far not so easy to pinpoint. When different practice between shifts regarding process control is identified, a potential for learning is identified as well. Some operators will have a more



complete and correct mental model while others will be more incomplete. This also implies that theories and explanations provided in a workshop are in themselves not enough to develop a more shared practice. After having discussed organisational and managerial frames in the next research question, I will return to how this can be developed.

When regarding the experiential learning cycle, the critical step in the learning circle is the active experimentation phase, where the tasks are to be executed in order to be evaluated. This step reveals the ability to learn as only limited learning takes place, unless the circle is completed. The outcome or lasting results depend upon the following up the new shared practice over time. The two workshops that have been reported as successful here, were both followed up by management. The investments made in modified automatic process control demonstrate this fact.

*“Operations workshops align differences between shifts, every operator learns more”*

, one operator stated. However the digester workshop revealed that not all had understood the new practice.

*“Some operators tend to go back to old practice. We would need a new workshop one year after the first one to have a new look at practice”*

an operator stated. The result from the digester workshop could be directly measured as a capacity reduction of 1,645 tonnes due to the specific chip plug split within the digester in November 1997 and shows the potential in using resources for problem oriented learning.

The core learning issue in complex systems is feedback. How do the production systems react to the way they are manipulated? Due to often long residual times, feedback is not given before next shift and in a shift cycle it can last for up to 14 days before an operator is back on duty. In the digester workshop, the production manager gave feedback in “Toftenytt” 10 days later and also in the written production schedule. In the lime kiln workshop, feedback was provided continuously as the process operators learnt that the quality of the burnt lime was good enough for further processing in their own department. Also, the process engineer followed up with chemical analyses of the burnt lime after the temperature reduction.

The other workshops at Tofte have, for various reasons, not left any detectable results in the form of better operational practice. As reported, in three of ten workshops a task list was not agreed upon. In the other workshops, task lists were made but not followed up. Due to the shift cycle, this task is better suited to daytime staff. The department process engineer has, in most workshops, been central in the prephase and in the conduction of the workshop. Thus, also the following up across shifts should be a task. However, at Tofte other tasks have come before follow up activities and the long term collective learning has not then taken place.

I have thus far shown the potential of workshops. I have also analysed why and how easily an OW may fail and often does so. In the next section, I will discuss how an OW can be regarded as experiential and individual learning.

#### Experiential learning at the level of collective and individual

As discussed with the experiential learning circle, the circle needs to be closed if learning is to take place. The resulting theories from learning arenas have to be tested in the various control rooms. In a process plant with a shift structure, it is of major importance to work systematically with collective testing of theories from a problem based learning arena. The four steps in the Kolb experiential learning cycle are 1) concrete experience, 2) reflective observation, 3) abstract conceptualisation and 4) active experimentation. The concrete experience will be the incident or recurring problem such as failures in insulating bricks in the lime kiln. Thus, this will be relevant in the pre-phase of an OW. Reflective observation and abstract conceptualisation takes place in the workshop where the problem is discussed. The active experimentation can be compared with what takes place in the control rooms afterwards. When an OW is not followed up, it cannot be regarded as experiential learning, since the active experimentation must be what all shifts agreed upon. This is still the major challenge for process control when the experiential learning circle is not closed.

#### Individual learning

A pedagogical strength of Operations workshops is that several methods are used in combination. The given problem or issue that is dealt with gives each person time to reflect on the questions. In the workshops, theories are provided in order to highlight the current issue, groups with mixed personnel discuss the question(s) and finally, each operator must test the new theories in order to see how they work. The experiential learning cycle is

implemented, thus each individual has to follow the four steps in the cycle if the learning is to lead to improved process control.

I have argued for the necessity of “knowing why” in a complex process plant. The methods used in an OW are means for operators at different skill levels to improve their knowledge of systems. They must know what to look for in order to predict what is going to happen. Such disturbances are covered in an OW. A process control strategy, given the disturbances and how to control them, is also a theme. Thus, what to look for and how to control it is covered in the workshops and serves as a guide for what to do in order to keep control when the process is disturbed. The more inexperienced operators will strengthen their “knowing that” while more experienced operators will gain a broader understanding of the problem and enhance on their different forms of knowledge.

Why is it in practice often difficult to close the learning circle? The process operators have, after an OW a better understanding of the problem and in most cases a shared notion of how to solve it. I have described a process plant as complex to control and also the Tofte production process where several systems are integrated between departments. Thus, deviations from one department will have consequences in others. The complexity and many deviations explain why it can be difficult to trace lasting learning in the form of changed practice. I have also discussed lack of “knowing why” as a factor for not learning from experiences. In the digester workshop we saw one example of using the old control strategy with a loss of 1,653 tonnes of pulp. The person responsible for this had not been present at the workshop and was not familiar with the new strategy.

What can be taken from the workshops thus far is that the problem oriented theories and discussions help those present to refine their mental models of actual production system. In order to close the learning circle, all shifts have to follow the new practice in order to verify the impacts of the changes. In Figure 6.2 there is an arrow to a new workshop to give feedback on the changes, the degree of success, or explanations to why the new measures failed. Thus far at Tofte, an OW has not been followed up in this structured manner even though differences in practice still exist.

As a summary of OWs, I will discuss how they relate to Ellströms’ requirements of learning systems and also contrast classic educational methodologies.

### *How Operations workshops meet requirements for learning*

When regarding the list given by Ellström presented in Chapter 4.4 and discussed in terms of Operator training, an Operations workshop actually fills all the four requirements for how learning should be performed at a plant. An OW develops from problems and developmental needs in the plant. This has been the case for each of the workshops so far at Tofte, and a lesson learned there is that the more problem oriented the OW is, the more likely it is to result in measurable and lasting results. The second requirement of being based on individual's experiences from problem solving in practical situations is also met. This is one of the main strengths with the workshop formula, as it must be based on how the operators actually handle the process. In discussions, various explanations as to why operators operate as they do will emerge, and this allows reflection upon how to change their practice in order to align it with other shifts.

The third requirement of learning being made in forms that enable dialogue between and within different groups of personnel and between personnel and experts within different areas, is, as has been shown, one of the central design criteria in a workshop. In order to develop a shared understanding of the production related problem between shifts, as many operators as possible have to be present. Also, due to the non-existing clear-cut limits between operations and maintenance, these groups need to meet in order to develop a shared view of how to handle problems and what should be improved in terms of production equipment. The fourth criteria, that the workshop is planned and executed in co-operation with those who are directly involved in the education process is partly met at Tofte. Thus far, the workshops have been planned and prepared by process engineers and production management. However in the workshop itself, all participants are of importance, when it comes to refining the problems and discussing possible solutions.

I presented the classroom attempt in the beginning of this chapter in order to make a contrast with OT and OW. From the analysis of OW and how the operators are more involved in problem-based learning, it becomes clearer why the operators preferred Operations workshops instead to classroom teaching. As has been shown, theories and explanations that highlight the problem at stake can be provided in the first part of a workshop. The general theories will then be connected with practice, and these theories will be utilised and further tested during the workshop. All these elements are typically missing in a classroom setting.

### A summary of Operations workshops at Tofte

There are several strengths of OWs as learning structures:

- Problem based learning form.
- Combines experiential learning with other learning types at the workshop.
- Integrates learning with working in problem solving.
- Learning occurs at the collective level in a cogenerated learning process where the core issue is to develop shared process control practice.
- In contrast to most classroom attempts, an OW fulfils the four requirements for how learning should take place.
- A task list provides a shared direction for necessary changes and development in operational practice.

Despite these benefits, Tofte has, thus far, in most cases not managed to utilise the benefits given by the workshop structure. Two of the first workshops were well prepared, problem oriented, workshops and which resulted in tasks lists, and tasks followed up over time. This also implies that Tofte's ability to learn from experiences in conducting Operations workshops has been limited. An Operations workshop depends upon the degree of problem orientation and way in which it is conducted. A specific topic is focused upon and theories and explanations are provided in order to better understand the problem. Thus, a better, shared mental model is the outcome. A task list from a workshop can be regarded as hypotheses that have to be confirmed or rejected, where either outcome is a valuable answer. However, resources have to be invested in a structured follow up phase extending beyond above the 8 hour shifts. Experiences from Tofte have revealed that suggestions tend to fade out over time and that the operators and/or shift management are limited in their ability to perform this coordinating task.

#### 7.1.4 Summary of learning systems

I have presented examples of two different kinds of learning arenas. These are Operator training and Operations workshops and they are both summed up individually as answers to my first research question on learning systems. The two arenas have been well established at

Tofte, however, to varying degrees in different departments. When regarding Operator training, it is still too early to conclude on its impact on results in the pulp mill. However, two Operations workshops have made positive contributions and demonstrated the potential of the method. The strength of these methods is the collective learning that takes place in cogenerated learning arenas. In Operator training this strengthens the master-apprentice method and in Operations workshops it gives a shared understanding and direction for further tasks in process control.

In Chapter 4.4, two modes of learning were discussed, these were adapting and developing directed forms of learning. Operator training aims at both learning forms, providing a basis for further learning in the control room covering the central aspects that have to be known in a department and offering correct explanations of causal inferences in process control. A well designed and conducted Operations workshop is a good example of developing directed learning (when it is properly followed up and is thus an example of how learning and development in a process plant ought to take place).

In this section I have analysed Operator training and Operations workshops for educational structures and content. How these two structures are used on the collective as well as individual level has been a core issue. In the next question, I will regard organisational and managerial frames as I analyse the implications for learning of different socio-technical structures.

## **7.2 Implications for learning of different socio-technical structures**

In this section, organisational and managerial frames for learning will be analysed. The research question is: “What is the implication for learning of different socio-technical structures?” In the analysis of Tofte (Chapter 2), the organisational change that took place in 1992 is described. With that change, Tofte moved in the direction of more independent or semi-autonomous shifts along the production line. However as Trist (1981) states: *“In established work organisations the accumulated practices of the past are present along with an array of vested interests”*. From the analysis of the Tofte plant, two major process control challenges were identified after the reorganisation: co-operation and responsibility distribution. Thus old habits were still in place at Tofte.

Characteristics of the old and new paradigm are given in Chapter 3.6 and discussed there. I will, in the following, analyse how use of learning arenas as structures can promote the change from the old to the new paradigm of work that is regarded as necessary in order to improve variance control. I will first analyse how use of the two main learning arenas structures tasks regarding boundary control and enables managers to be facilitators for learning and how operators' knowledge and skills are better utilised and thereby developed. I will end this section with a discussion of how Toftes' experience with learning arenas is a contribution to theories in socio-technical literature.

### 7.2.1 Learning arenas and structuring of tasks

I have, in the theory section, argued that, with features and characteristics given by the production technology itself, a plant cannot be controlled through a traditional tall hierarchy. This is central in "the new paradigm of work" as managers need to be facilitators for learning in contrast to controlling and directing the operators in a plant. Operator training and Operations workshops, as learning arenas, provide structures to help process engineers and managers in their task of being facilitators for learning.

#### *Structuring of tasks in Operator training*

In this section, I will discuss how OT has given opportunities to change managers' tasks regarding operators' knowledge and skill development and the fact that this is (or at least should be) a major managerial task. I will do this by discussing each managerial office or group that has responsibility for knowledge development in the production department.

Management at the strategic level: The top-level support of OT is demonstrated by the fact that development and use of OT is in line with the production manager's desired changes and improvements to operations in the plant. Tofte now has the tool the plant did not manage to develop through LOOK 92. The production manager has also taken the initiative for meetings and been eager to progress and get results and has also encouraged the stakeholders to keep on. However, progress at Tofte has been slow and it is ultimately the responsibility of the production manager to allocate resources to tasks regarded as important.

The shift management: The shift manager has the responsibility for the professional development of all operators on his shift. By having Operator training, the task of following up professional development, both on the individual level and on the group level in the control rooms, has become more effective. The shift manager now has a tool which assists in the task of following up on progress and, at the same time, the possibility to initiate debates in the control room about specific questions. As one shift manager has stated:

*“Through this model, a lot of questions are raised that would never have come up earlier”.*

A main benefit here is that the shift manager now has a far better tool to assess whether an operator should be promoted to a new position. The shift manager has better control of the candidates' minimum level of knowledge and skills. This has earlier necessarily been more haphazard. The trade certificate has been one criterion, however, this only covers one of the three to four departments that are found within one control room. Because of the desire to have redundancy of functions, with more operators able to rotate between different jobs and also strengthen their ability to understand the impact of disturbances in neighbouring departments, there was a need to structure this task.

The orchestrating role of shift management has become clearer: instead of giving orders of what to do, OT enable operators themselves to see what needs to be done. The shift manager can, instead, motivate work with the phases in the Operator training programme and thus act as a facilitator for learning. Also, the concept of boundary control becomes meaningful in terms of the boundary around a shift in the control room. The shift manager can concentrate on cooperation and progress in the control room by having tools and resources for knowledge development to hand.

The process engineers: The process engineers at Tofte are chemical engineers with a university degree. After the reorganisation in 1992, their tasks regarding operators' and apprentices' education became more unclear than before. With the Operator training model, the process engineers have more distinct tasks regarding operators' education and training. The tasks are performed according to work descriptions for operator education and training; the process engineers also have a professional responsibility for apprentices. They participate with the ORE and control the quality of developed phases. They may, of course, help apprentices and operators who are being trained, and they have an important task in the final



test to ensure that the candidate really understands what new responsibilities are involved with the new status. Thus, the OT model, to a large degree, structures the educational tasks related to operators and apprentices for the process engineers and the engineer's general models may be used to refine questions. One process engineer who has understood this task said:

*“We have to develop to a situation where operators take trend curves and analyse situations. It should be unnecessary for engineers to do it. I regard it to be my mission to give operators theoretical input.”*

In all industry with a shift and daytime organisation, uncertainties in tasks and responsibility distribution will arise. The OT model clarifies the process engineer's tasks regarding the education of operators within their departments, and has relieved many of the remaining uncertainties at Tofte which existed after the failure of “LOOK 92” regarding responsibility distribution and cooperation.

The co-ordinator: The need for a co-ordinator arose with the introduction of OT. There was a need to have a person to keep the contact with Peterson Linerboard Moss and to co-ordinate activities of the OREs, such as reporting worked hours. At Tofte, the co-ordinator had been a process- and laboratory operator, she was asked by the production manager to take the co-ordinator job. At that time, she was tired of shift work and she admits that she was among the people who complained about how bad she felt the operator training programme at Tofte was. This has proven to be a wise move: as a co-ordinator in the operator group, she has turned out to be a positive force in the organisation.

*“I admit I was one of the people who complained before, and now I got an opportunity to do something with it myself.”*

Until 2001 she also was a member of the educational council that took over for the “LOOK 92” steering committee. The central education manager (a chemical engineer) has now taken over her tasks.

### Structuring of tasks in Operations workshops

In this section, I will look at how an OW structures managerial tasks concerning collective and experiential learning, and thereby variance control.

An Operations workshop structures the task distribution between shifts, department management, and process engineers at all stages of the workshop process. The process engineers will naturally have a central task in the co-ordination the practical arrangements of a workshop. They have also had central tasks in making the analyses prior to the workshops. In the workshop, they and other managerial staff have contributed with more general theories as was the case, e.g., in the digesting and bleaching workshop. As “outsiders” in the model of co-generative learning (Greenwood and Levin, 1998), they have more general context-free models and they will be provided with local theories and thus refine their own mental models. The learning arena structures communication related to problem solving and development such as optimisation measures. Two statements from operators emphasise this:

*“We could be very much better if the operators and engineers joined forces.” And “We should have coupled the engineers’ theoretical knowledge with our more practical knowledge. We could have been a very strong team.”*

This is what takes place in a well prepared and conducted OW. The process engineer, who has no direct production responsibility, needs such an arena in order to interact with the shift workers. A shift manager stated:

*“An operations workshop is excellent aid to shift management.”*

“Their” operators become involved in making decisions regarding modifications and at the same time develop their process understanding. Shift management also gets more knowledge about on what and how to follow up important aspects of production. The production manager has a tool to use when there are production challenges to be resolved through a combination of shifts and daytime-based maintenance. Initiatives, theoretical contributions, and presence in wet pulp workshops have taken place this far. The production manager supports and encourages his organisation to use resources to promote this way of working.

When Tofte was reorganised in 1992, the maintenance functions were split up and moved physically closer to the production departments. But, the organisational division between operations at the levels of shift and maintenance and equipment development still exist. This division of responsibility creates a need for very tight and well-oiled co-operation between the two organisations. The STS principle of redundancy of functions vs. redundancy of parts (Trist, 1981, van Beinum, 1988) regarding operators trained both in operations and maintenance, has not yet come into being at Tofte. At many Employeeship courses, discussions about “them” and “us” were reported, meaning that mutual understanding was missing. An Operations workshop serves as a means to integrate operations and maintenance and give the two groups new insight and to solve practical problems that are of concern of both groups. It is thus a means for core functions to absorb support functions.

I discuss the close interrelationship between operations and maintenance in Appendix 5. The task lists given in the summary reports from the workshops that are approved by the various community-of-practices show the close interdependencies between operations, equipment and maintenance. A workshop may be very useful to the production department in that it helps to make priorities when considering how to improve equipment, routines, and operational practice. Especially the instrumentation part of the maintenance function benefits from taking part in an operations workshop, since this is tightly integrated with operations in the process control systems. Calibration routines, changes in controllers, and reprogramming of advanced control (cf. the digesting workshop) are examples. The Operations workshop also serves as a structure for process engineers and management to be facilitators for learning. In the co-generated learning model they are regarded as the outsiders.

In terms of task distribution as regards knowledge development and combining this with problem based learning, Operator training and Operations workshops, have thus far at Tofte, proven to be good models and practice. The use and development of the educational models at Tofte has structured the managerial tasks regarding operators’ education and training. However, as the number of Operations workshops in four years has only been ten, and the follow up of these workshops have been performed to a limited extent, these tasks have not taken too much of the available time.

In the next section, I will discuss how operators’ knowledge and skills are utilised in the Operator training and the Operations workshop model.

### 7.2.2 Utilisation of process operators knowledge and skills

In the new paradigm, the need for people to be developed as resources is stated. Process operators represent a significant resource and in fully automated plants their knowledge and skills are not always sufficiently exploited. As more operators have also attended secondary technical schools, they also want possibilities for a professional development during their career. Skule (1994) outlined the lack of possibilities for skilled operators in the food processing industry to employ their new skills. In a pulp mill, the possibilities for employing knowledge in monitoring and controlling the various processes, are better. This is, however, based individually on each operators' motivation. A broader utilisation of operators' knowledge and skills needs to be organised and structured.

Utilisation of operators' knowledge and skills in Operator training: In the OT educational programme, responsibility is delegated to the operators and the eight OREs, these are the main people involved in making and organising the educational material. With this allocation of responsibility and tasks made possible by following a new model, new possibilities for participation in plant development are created. They have all stated that the need for change and personal growth after years in the same position is their main motivating factor. In addition to learning their own departments in depth, they use their knowledge in structuring educational material into phases and formulating questions and solution proposals.

Other operators may use their knowledge as well in challenging the solution proposals as well as participating in the development of phases and formulation of new questions. So far, some assistance has been given in two departments, but this has been difficult to accomplish at Tofte. However, some solutions to questions have been modified due to operators having another explanation that the ORE and process engineer had not thought of.

By following and developing the OT model, eight operators utilise their full potential while they also learn themselves. Thus, the OT model combines learning with working. In addition, it opens possibilities for other operators to assist, supplement, and comment. Their experiences are taken into account and will thus be shared with the other shifts.

What the operators have also learnt is that they are entrusted with important tasks such as development of their own colleagues. This was emphasised by the co-ordinator in a LOOK

steering committee meeting early on in the process. At that time she was not a regular member of the committee, but was asked to participate in a report on how the operators were working. She also reported to the committee about feedback she had received: *“So you (management) finally have confidence in us?”* Instead of alienation and being passive receivers, the operators are now more actively involved.

A process control goal is stable processes with as few deviations and disturbances as possible. In quiet periods, when this is the case, process operators may have time left which can be better utilised. This is, however, often a challenge as tasks in parallel with controlling a department must not disturb the work of an operator too much or for too long. At Tofte, those operators that thus far have been most active, are the OREs in Operator training. Although they have done most of the work outside of normal working hours, they have truly utilised their knowledge and skills. Also, other operators have the possibility to participate in modifications of questions and answer proposal. In many cases, those operators who follow the model contribute with answers that become a new standard answer proposal.

While “LOOK-92” was developed by “external experts”, OT is developed by experienced operators in co-operation with process engineers in a cogenerated learning process. The OT model thus fulfils point 3 in Ellströms’ requirements of a good learning model. It is also planned and performed in co-operation with those who use this form of education as its execution is adjusted to the other tasks that have to be performed in and from the control rooms.

Utilisation of operators’ knowledge and skills in Operations workshops: A main aim with an Operations workshop is to solve defined real-world problems. In order to do this, the process operators’ knowledge and skills from their experiences with the problem are invaluable. As such, an Operations workshop is an arena where operators have excellent possibilities for valuable contributions, at the same time as having possibilities for refining their models of the production processes that are being discussed. An operator summarised her experiences with workshops this way:

*“In an operations workshop, you have a real feeling of participation in something useful. You may get another attitude toward daytime personnel when working together with them. Otherwise a division can develop between operators and daytime workers including*

*management and project engineers. Operations workshops should be a natural part of daily work”.*

Pasmore (1988:79) states that

*“Since effective variance control typically requires learning new skills and taking on additional responsibilities, employees often welcome the opportunity to become more involved in making the technical process run more smoothly.”*

Learning variance control in combination with working is accomplished in Operations workshops.

Participation in an Operations workshop at Tofte is a voluntary task. Those who participate are motivated and also expect that the workshop will lead to practical changes such as new and shared practice. (The OREs from Operator training have been present at all workshops that cover their department). The level of attendance at a workshop is revealing –both of the general interest in the department and the belief that the workshop will bring results. If it is not regarded as interesting enough, or that no results will emerge from the workshop, people will use their free time differently, even though operators are paid overtime for attending. If the operators withdraw their support, what is left is a traditional managerial planning meeting. A process engineer stated it this way:

*“It is important to follow up the task list that is provided at the workshop, if not we may risk that the operators withdraw their support.”* (This was what happened to the “forums”).

Thus far, the level of attendance has been stable and the programme of co-operation and sharing of experience is still in place. At the end of the turpentine workshop, the process engineer who was in charge of the meeting stated that he regarded a workshop primarily as problem-based learning. One operator wanted one workshop per department per year.

*“Even if there are no particular problems, there are always things that can be done better.”*

There was common agreement that Operations workshops are a good method for making decisions and finding solutions. The task lists are a result of a democratic process at the

workshops, and the decisions will be better as all involved parties at the workshop have an opportunity to argue for their point-of view. Therefore, it is of utmost important that there is a “critical mass” of operators present. By critical, I mean enough operators to convince the other operators not present to follow the new practice. If operators do not show up, they have no right to complain about decisions made. Since the operators influence the decisions made at the workshop, implementation is made easier as it is based on their own suggestions.

### **Interactions and synergies between the arenas**

So far, I have treated the arenas separately. Operator training at Tofte will serve as basic education in the control rooms and will raise the level of knowledge as a whole in the control room, not only for the candidate. When the “knowing why” level is higher, individual experiential learning will take place more easily and proficiency and the level of expertise can be increased sooner as more thorough explanations are provided. Operator training aims at a higher level of knowledge than is usually required for passing the trade certificate examination. Also, as the trade certificate only covers one department within a control room, efficient education in other jobs within a control room is provided which facilitates rotation between departments and thus helps develop redundancy of functions.

With more operators taking part in rotation and having a higher level of knowledge, they are better enabled to take part in more Operations workshops and are more able to discuss the proposals from the workshops, both at the workshop itself, and when tasks are to be followed up in the control rooms. Results from an Operations workshop can be captured in Operator training, such as new routines or something that should be given special attention. Questions can be constructed and the explanations from the workshop can serve as the solution proposal. In this way, questions based on experiences from production that may require in-depth understanding can be stored. Thus far at Tofte, all OREs have participated in relevant workshops and thus able to perform this transmission between the two arenas.

I have thus far, shown how the use of the two learning arenas structures tasks in a shift organisation and how the same structures enable managers to become better facilitators for learning. Development and use of learning arenas is a good example of how it is possible to combine learning with working and thus better utilise and develop process operators’ knowledge and skills. Both of these aspects are central in socio-technical system design. I will, in the following, further analyse how the practice in OT and OW support the change

from the old to the new paradigm and its implications for learning before I look at how process operators can better utilise their time on developing directed tasks.

### 7.2.3 Learning arenas as tools in STS design

In this section I will look at variance control and the importance of the control room as the learning entity.

At Hunsfos in the Industrial Democracy Programme (Engelstad, 1970b), the variance matrix method was provided by production experts in order to detect sources of deviations, to identify where they made impact and the degree of that impact. According to Pasmore (1988:79)

*“...one objective in STS design is to move the expertise that has been developed by specialists in variance control to the point at which variance occurs. Preferably, skills in variance identification and control should be transferred to those who actually perform the work, since they are in the best position to spot variances and do something about them immediately.”*

In an Operations workshop at Tofte this is a design criterion. The origin of a variance (disturbance) and its various impacts are discussed in a dialogue between operators and engineers (management). What is also provided is not only the analysis, but, at the same time, suggestions as to how operational practice and/or technical modifications may remove or at least minimise the deviations. Thus, the analysis is no longer expert dominated, but cogenerated between experienced operators and management and is used directly to find testable solutions. Operations workshops at Tofte have been used to detect and analyse variances within single departments in control rooms, to see how deviations propagate within one control room (e.g.: fluctuations in kappa number from digesters to the bleach plant), and to see how deviations may originate and propagate to departments controlled by other control rooms. An example here is the gas systems that originates in the wet pulp department where the spent liquor is flashed in pressure releasing devices after which the gases are treated and destructed in the lime kiln. When deviations occur it will be in form of fluctuations in the pressure of the gasses and, in serious cases, flammable liquid (turpentine) in gas tubes. The workshop enabled the operators to be aware of disturbances and how they impact the other departments and thereby developed knowledge of why they must be kept under control.



Operations workshops are thereby a tool in complex variance control. They connect the various organisational levels of operators on different shifts, management, and the daytime organisation with the various maintenance resources. The inclusion of all of these groups is necessary in order to analyse problems and implement solutions. This kind of variance control has proven to be successful, as discussed in Chapter 7.2.2. The contribution of Operator training in variance control is to enable each operator to predict what is going to happen and thus be better able to control disturbances before they impact the wider process.

If redundancy of parts (one man, one task) with tight managerial control is a design criterion, the operators will lack the possibility of learning from each other in the control rooms. The ones who will learn from experiences are the engineers, whereas the operators are reduced to expendable spare parts. In such a system, no Operations workshops would take place. The number of available operators for a workshop would, in the worst case, be restricted to a maximum of five, but it would also be a function of management to solve problems alone. Also, Operator training would not take place as no operators would have been entrusted with the task of developing educational material.

I have, throughout this thesis, argued that this way organising for variance control and of perceiving people, is, in practice, impossible. A high level of knowledge in the control rooms is a bottom-line prerequisite for the development of more autonomy in the control rooms and to enable operators to take responsibility in process control. Also, the more operators know, the more they are involved in the development of their work (as is the case with the ORE). Thus there are, in practice, no real options as to how a plant must be organised in order to have a more competent and motivated staff. However, differences in degrees between the old and the new paradigm of work exist between plants and also within plants in the relationship between shift management and operators in the control rooms. A formal structure is never a guarantee as to how management perceive workers. At Tofte before 1992, one found engineers and managers acting as facilitators for learning. And in an organisation with an espoused theory (Argyris & Schön, 1978) of independent control room operators, some managers are still afraid of what they regard as losing control.

Development of semi-autonomous groups must be regarded as a learning process, and this learning will naturally be different between shifts and control rooms. The more operators in a

control room are able to do, the more they can be entrusted with the process control. Some shifts were working well together as a team; they overlapped (redundancy of functions) and used the shift to discuss various solutions to problems. The ability to make decisions and solve problems within the group in the control room has increased from 1996 to 1998.

Each shift in a control room can be regarded as a community-of-practice, as the operators, over time, develop their own way of communicating and acting. When an operator is placed on a shift in order to learn how to operate a department, he/she will be strongly influenced by the colleagues on that shift. In a control room, the operators are “forced” to spend their time at work physically close to each other, given by the layout of the control rooms. An operator spends most of the working hours in the control room.

*“We know our shift colleagues better than our own family”*

is a common comment at Tofte. The control room as learning environment is thereby central. The salary system at Tofte encourages operators to learn more tasks and thereby increase their internal flexibility. In case of disturbances, this is a good support mechanism for operators as they are always at least two people that can cooperate in analysis and troubleshooting.

STSD provides theories about how people are to be regarded and managerial frames for that. The two main learning models at Tofte would not have taken place if Tofte had not been in a transformation phase in the direction of semi-autonomous groups in the control rooms. I have also, in this chapter, based on experience from the two cases, found that, by utilising the possibilities given by the two models, there are not just economic benefits (the lime kiln and digester workshops) but also the benefits of learning in combination with working. Organising an environment for learning to take place in a cogenerative way in a learning arena is a means to practice the principles within “the new socio-technical system paradigm” (Ref. Table 3.1. in Chapter 3.6). It is a tool for “joint optimisation” as better understanding of production technologies is to be transferred to the production staff. When following the learning arena model, people are clearly regarded as complementary to the production equipment and as a resource that needs to be developed. Learning arenas are arranged with the purpose of giving the participants multiple skills and to give them better process understanding in order to improve their internal control. A learning arena based on cogenerative learning has, per definition, a participatory style and is a “bottom-up” as well as

“top-down” learning model. A learning arena is further based on collaboration and collegiality and serves to not least fulfil operators’ psychological job requirement for learning. If learning arenas are performed in a manner that the members find meaningful, commitment may be an outcome as well. Finally, a learning arena is a safe place to provide innovations. An operator put it this way:

*“Operations workshops should be a part of daily work”.*

Participants learn how to learn. This is what Argyris and Schön (1978) identify as deutero-learning.

#### 7.2.4 Learning arenas and impact on developing directed learning

I will sum up Tofte’s experiences of development and the use of learning arenas with the impact they have had on developing directed learning. Four basic elements must all be in place in order to claim that an organisation has this kind of learning:

1. Good educational structures
2. Sufficient quality
3. Organisational frames
4. Managerial frames

The two first points are covered in the answer to the first question. In contrast to classroom teaching the two educational structures have proven to be means of developing process understanding and tools for variance control. Two of the first workshops have proven effective at solving the problem at hand (split in chip pile and lime kiln failures). These two workshops were both followed up. Operations workshops have gained a strong position at Tofte and are supported all the way from top management to process operators. It is, however, a fact that the number of 10 workshops in four years is modest and that both content and following up activities all have potential for improvement.

“Sufficient quality” is a requirement for a content and level that provides “knowing why” in addition to “knowing that”. In Operations workshops, “knowing why” is provided via problem-specific theories used to highlight the current issue. The learners see why the theories are provided and that they have been used to enhance the knowledge of experienced operators as well. In Operator training, the content and level is given by the questions in the different programs. Experiences thus far show that more “knowing why” can be provided in many of these; this will be discussed more closely in next question.

The third requirement implies a certain degree of redundancy of functions. When comparing Table 3.1 with Figure 3.3 (redundancy of parts vs. functions), I have argued that an organisation with redundancy of functions, i.e. developing multi-skilled operators, will be better suited to promote development-oriented learning. Also, a degree of freedom in tasks has to be in place in the organisation if developmental tasks are to take place. In order to take responsibility, it is a managerial concern to organise for learning so that the operators have the knowledge and skills necessary to predict what is going to happen. This is a basic requirement in variance control and a goal in developing directed learning. Toftes’ slow progress in Operator training is due to a lack of resources which has resulted in a situation where the OREs have had to use their free time when they were developing educational material. In parallel with this, they have had candidates following the phases. This challenge is further treated in next question. The lack of lasting results from most Operations workshops can be seen as a proof that Tofte still has challenges in the continuous work of maintaining and developing their practice.

With structure, content, and organisational freedom in place, the fourth requirement regarding managerial practice depends upon the theories in use. It depends upon how the operators in the control rooms are regarded and how management behaves as facilitators for learning (as contrasted with order-giving). In order to take responsibility for the production and for bigger process areas, the executing staff need to be given responsibility. Also, management, at a strategic level, have to make priorities about what it is important to do first. When a decision is made, sufficient resources must be provided for the task.

I have, thus far, dealt with Toftes’ programme of Operator training and Operations workshops until April 2000. I have just looked at four requirements that have to be in place in order to have developing directed learning. These four requirements are interconnected, as the

structures would not have been developed unless a belief that operators are resources was being developed. At Tofte, variance control as cogenerated practice has taken place. This is a theoretical contribution to STSD. The cogenerated practice has proven as an effective means, but, in most cases, this structured collaboration has for various reasons, thus far, failed. Thus Tofte's ability to learn from experiences definitely has a room for improvements, included here is the use of Operations workshops as learning methodology.

In the final question I will, based on my findings from Tofte, recommend how the learning arenas can be further developed in order to facilitate more developing directed learning.

### **7.3 Further development of learning arenas at Tofte**

A process plant needs systems and structures for knowledge enhancement. Without such systems, as was the case at Tofte from 1992-1996, education becomes too haphazard. With Operator training and Operations workshops, Tofte now has learning systems. How these are utilised thus far at Tofte has been analysed. I have also uncovered a need for improvement both in structure and in organisational and managerial frames. I will therefore, in this section, answer the final research question of how the learning arenas presented in Chapter 6 can be further developed. In the two Operations workshops given in Chapter 6, I provided production statistics that show that these efforts have been successful and that this way of working should be the way Tofte combines production optimisations with learning in the future. In the following, I will analyse various factors and describe to what degree Tofte as organisation has developed. Has collective and individual learning from the arenas resulted in organisational learning that can be traced as measurable results? This will be a background for the discussion of why and how learning efforts at Tofte need to be further developed.

I stopped data collection from Tofte in September 1998. For various reasons I have not been able to finish work on this thesis before autumn 2002. Before I recommend what Tofte should do in terms of structural and organisational tasks, I will give a short description of educational and managerial development that has taken place in this period of time.

### 7.3.1 Tofte development 1998-2002

A management training program: Late in 1998, a shift management training program started. Since then 8-10 meetings lasting 8 hours have been conducted per year. Shift management, the production manager and a consultant were present at these meetings. The goal has been to develop managerial practice with team-building in shift management, team-building in the control rooms, and more focus on the relations between shift management and operators in control rooms. Different measures to facilitate team-building have been tried out, and experiences of these are discussed at the meetings. How to enable the operators to become more independent and to take more responsibility, has been a central topic. In the autumn 2001, the shift management group decided that each shift manager should get an extra responsibility for a given department. And an agreement was made in the group to have two Operations workshops per department per year. As will be shown, this has resulted in more workshops in 2002. Also, the lack of progress in Operator training is a topic at these management training sessions. When I discuss improvements in Operator training, I will return to this.

With these meetings, shift management are provided with theories and experiences of how to develop more independent teams in the control room. The managerial focus on Operations workshops and Operator training as tools in this work has also increased.

A productivity programme<sup>57</sup>: Since autumn 2001 a productivity program has been run at Tofte. This is initiated centrally from the Södra main office in Växjö, Sweden, and is in principle identical in all the 5 pulp mills in Södra. It consists of idea generation, an analysis period of all incoming ideas, a selection phase of best ideas, and finally “waves” of implementation. When the selected ideas are to be tried out, the person who initially had the idea will be partly responsible for its implementation. In the idea generation and selection phase of 3 months, 15 people from Tofte were engaged full-time. Of these, were nine process operators. In 2002, four persons at Tofte continued full-time in the programme with implementation of 104 selected ideas. An important factor in the programme is to calculate the benefits of the various ideas. Operations workshops on different themes have been based on ideas from operators; the workshop on the vaporisation plant and the drying machines

---

<sup>57</sup> Called VHF – Verdier, Handlinger og Ferdigheter or in English: Values, Actions, and Skills

were a result of operators' suggestions. The productivity program has been run at a full organisational scale, and resources from the line organisation have been allocated on implementation. As a tool, to stay competitive, this productivity programme will continue. But it will be more integrated in the line organisation. I will soon return to how this may practically be done, as this is not yet decided.

Development in Operator training: I have, in Table 6.1, given the status of the educational programs and progress made for the operators per April 2000. This represents the number of candidates having finished in the period April 2000 until October 2002.

**Table 7.3 Status of Operator training per October 2002. (Status per April 2000 in parenthesis)**

	Department	Approved operators / apprentices	In progress
1.	Unbleached pulp	11 (4)	7 (9)
2.	Bleached pulp	10 (5)	8 (8)
3.	Drying machines	13 (1)	10 (5)
4.	Vaporisation / causticizing	4 (2)	2 (4)
5.	Recovery boiler	0	2 (0)

No progress is made in the wood department, or in the boiler and water purification plant. Tofte still lacks operators in these departments that are able to or willing to take this task. The department with the best progress is the drying machines. However, it is still, in 2002, a general worry for production management that the progress is too slow. In 2000 more emphasis and responsibility was put on the tutor for each operator or apprentice following OT. The main difference was that the tutor would take over more of the tasks that the ORE had in following up the candidates, with theoretical and practical phase tests and more practical tasks such as delivery of new phases and solution proposals as the candidate makes progress. Even though this is defined as a part of operators' work, Tofte decided to increase the salary of the tutor over a predefined period of time. This time period was defined in a contract between the candidate, the tutor, the ORE, and the shift manager.

Another measure was decided at a meeting in October 2002 with production manager, shift managers, process engineers, and OREs present. A more formalised group in each learning department will now have the responsibility for task distribution and progress /

implementation of training. The group will consist of the shift manager (leader of the group), the ORE, tutors, and the process engineer. The central training manager will also be present at meetings. In contrast to the first years of Operator training, shift management is much more engaged in training programs and developments taking place in the control rooms. This development can be regarded as a result of the management training sessions.

Developments in Operations workshops: In the four years from September 1998 until October 2002, seven Operations workshops have taken place. As can be seen from this Table, the activity has been low with only one workshop from August 1998 until January 2002.

**Table 7.4 Operations workshops 1998 – October 2002**

Datum	Department	Topic	Background	Attendance Total/operators
291100	Vaporisation	Stabilise black liquor dry solid content	Less deviations to the recovery boiler	19/12
150102	Bleach plant	Poor washing	Too high chemical consumption	28/16
300102	Continuous digester	Runability	Unstable production	14/7
020305	Bleaching chemicals; ClO <sub>2</sub>	Chemical reactions and reactor conditions	Too low gain factor	25/15
140302	Vaporisation	Productivity program ideas	Improved productivity	20/8
170902	Drying machines	Conduction of ideas in the productivity program		11/8
171002	Vaporisation	Productivity program ideas	Follow up last workshop	11/3

The vaporisation workshop in November 2000 was conducted during daytime because of the recovery boiler failure. This resulted in a more stable dry solid content in the black liquor fed to the recovery boiler. Again a focused process control goal increases the possibility for lasting results. However in 2002 the activity has again increased. This is due to the new initiative from shift management. How the tasks are distributed between shift management and relevant process engineers, is a matter for discussion in each case.

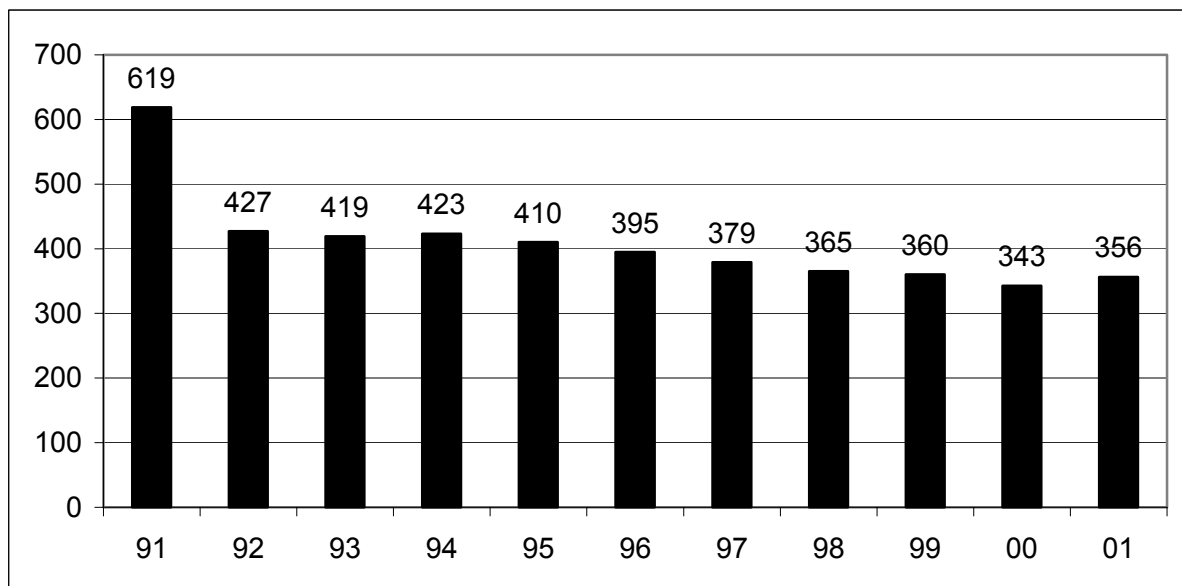


The bleach plant workshop was conducted twice in order to reach as many of the operators and members of shift management as possible. This was also a focused workshop, but no analyses have been made over time to trace lasting improvements. Another interesting improvement has taken place in the vaporisation department, here there now is continuity, and the latest workshop was also used to follow up on the previous workshop.

In the next section, I will look at production statistics before I end this chapter with suggestions for improvement.

### 7.3.2 Analysis of production statistics

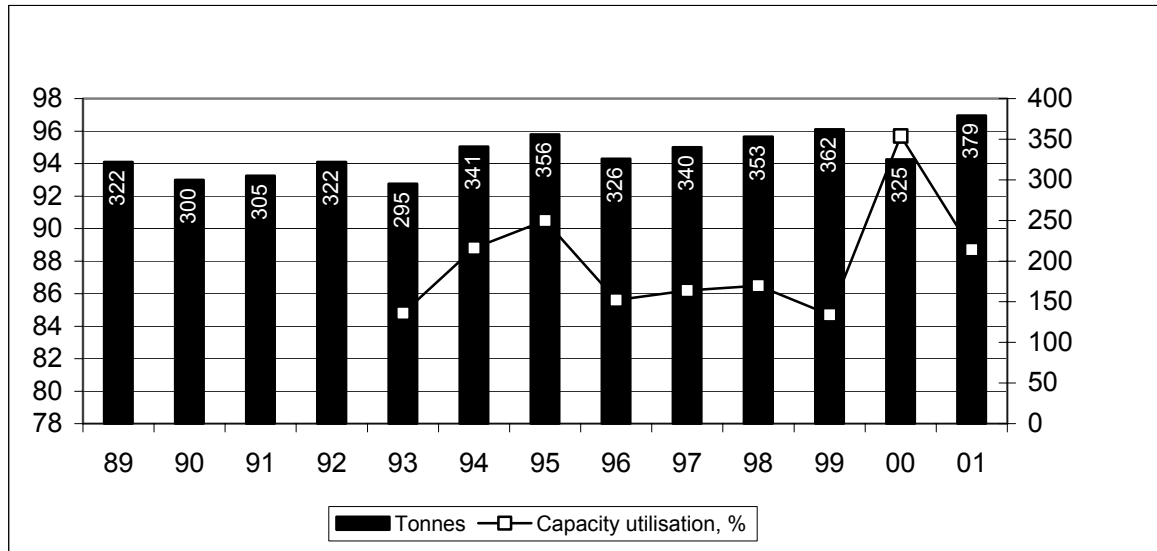
In this section I will look at developments in manning, production, quality, and overall costs in an attempt to trace the impacts of the two main learning initiatives.



**Figure 7.1 Development in number of employees at Tofte**

Figure 7.1 shows the development in positions from 1991 to 2001. The drastic reduction in 1992 is due to the “B-91”- project. Taken together with Figure 7.2, this shows a positive development in productivity per employee. Better routines, computer networks, investments in automation and mechanisation, and a generally more skilled workforce are the main explanations behind the figures. With the given production equipment, there were no plans for further downsizing. On the contrary, efforts were made in 1999, in the production section, to

strengthen operations with 10 process operators. Plans have been made to have one extra operator on each shift at the drying machines and four in the other departments. Tofte still has a challenge in recruiting competent staff.



**Figure 7.2 Development in production and capacity utilisation**

In 1989, 1995, and 2000, when the product prices were high, a production bonus was paid to all employees. This is one explanation for the high production and capacity utilisation during these two years. In 1992, 93, and 96 the production was reduced due to a decline in the market. Changes as a consequence of the “Tofte 350”- and later the “Tofte 400” project, explains the increase in production per year. The capacity utilisation is a good measure of how well the plant is being run, has not been impressive in the years from 1997 to 2001. These years are the relevant years to judge in this thesis. However, since the major overhaul in October 1999 the capacity utilisation was 91.2 % in the final 11 weeks, while it was only 82.5 % in the 41 first weeks. This positive development continued in 2000 until the failure in the tubes of the recovery boiler in September 2000 with a loss of ca. 87,000 tonnes. The capacity utilisation was then 95.7 % which is the highest ever. In the years 96 – 99 the 3 drying machines contributed to the biggest losses in production. In the overhaul in 1999, necessary maintenance was performed, and a salary bonus was introduced to yield for the start-up week and thereafter for the rest of the year. And the manning while producing short fibred pulp was increased with one person per shift and this person was dedicated to follow and adjust the pulp web from the raw sections into the fan drying section at the two smaller

machines (1 and 2). With a higher availability on the drying machines, the wet pulp departments could be operated at a more constant rate and variations are thus reduced. This development also shows that Tofte possess the organisational ability to produce at a more stable rate.

The development at the drying machines and the production rate from autumn 1999 until autumn 2000 shows the potential in the Tofte organisation and that knowledge and skills at the present time is available to keep up this high production rate. However, in 2001, capacity utilisation was down despite a new production record. This was due to many stop- and start situations and, as has been discussed, the process operators are far more challenged during unstable production and in stop-start situations that occur too infrequently for experience to be built up.

**Table 7.5 Development in percentage of off-grade products**

Year	1997	1998	1999	2000	2001
%	9.0	9.4	6.9	11.0	10.0

Off-grade products are a result of impurities such as plastics, fractions of uncooked pulp, too low brightness or wrong fibre length for a produced quality. In the transition between short and long fibre pulp, there will be a zone with mixed fibre pulp. It is a production measure to minimise this amount and how well this is met, is a good measure of how well the production is run. However, in 2001, this percentage was at its highest ever. The major factor causing this was severe wear and tear in the chip screening department. This resulted in many stop-start situations with propagation of deviations as result. Besides this, the small chip digester was fed with a higher fraction of bigger chips resulting in more uncooked chips that the following screening department did not have the capacity to handle. Minor fractions of uncooked pulp were found in the pulp. Results in 2002 are improved as per September with an off-grade fraction of 6.4 %. More focus on and knowledge of kappa factors from the digester and better capacity in a modified oxygen delignification plant are the main factors here. The degree of better operational practice is not possible to estimate. Thus, also here Tofte has challenges for better performance.

Measures that were mentioned by Peterson Linerboard Moss when they were asked if they were able to report any results from their Operator training program included less effluents

and it was claimed that this was due to better production knowledge. Environmental measures are results of production design, production rate, equipment condition (maintenance standard), and operational practice. The following Table shows development in chlorinated compounds (AOX)<sup>58</sup>, SS, and COD. The major improvements are due to modifications in the bleach plant, but also a more integrated washing cycle (see Chapter 2.4.5). Effluents from Tofte to the sea are well below the limits given by the Norwegian Pollution Control Agency and have been stable in recent years. Thus it is not possible, at Tofte, to relate Operator training to reduced environmental impact.

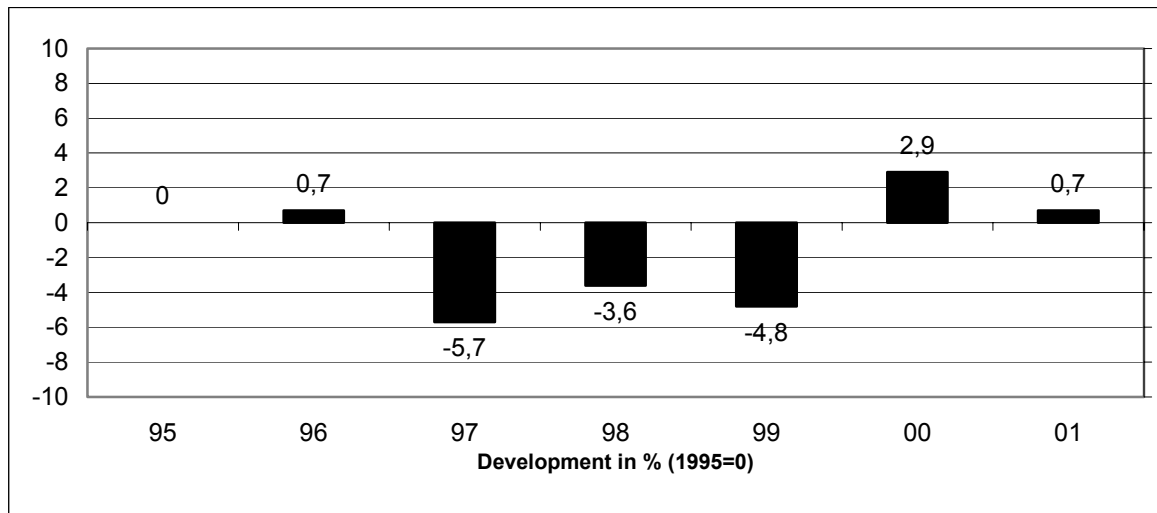
**Table 7.6 Tofte effluents; COD, AOX and Suspended solids (SS)**

	COD		SS		AOX	
	Effluent in kg/t	Permissible limit	Effluent in tonnes/day	Permissible limit	Effluent in kg/t	Permissible limit
1986	73	95	2.5	4	7.7	7.5
1987	79	95	4.6	4	7.7	7.5
1988	87	95	5.6	4	6.6	7.5
1989	72	95	3.3	4	5.3	6.0
1990	60	95	2.7	4	4.5	6.0
1991	59	95	2.7	4	2.7	6.0
1992	45	95	3.6	4	0.4	4.0
1993	31	70	1.9	4	0.2	2.5
1994	26	57	1.8	4	0.16	2.0
1995	28	57	2.3	4	0.15	2.0
1996	24	57	2.0	4	0.15	2.0
1997	28	57	2.0	4	0.15	2.0
1998	30	57	2.3	4	0.15	2.0
1999	34	57	2.3	4	0.15	2.0
2000	36	57	1.7	4	0.24	2.0
2001	35.5	35	2.3	4	0.23	0.3

<sup>58</sup> Adsorbable organic halogen. A method of determining the amount of chlorine or other halogens bound to organic compounds (molecules).

COD = Chemical Oxygen Demand. A measure of the oxygen consumption during the breaking down the organic material in the effluent to carbon dioxide and water.

SS = Suspended solids. Particles suspended in a liquid.



**Figure 7.3 Development in overall costs pr. tonne inclusive depreciation**

As regards costs, these have been reduced since 1995 despite investments in the “T400” project. The negative development in 2000 and 2001 can mostly be ascribed to increased capital costs due to the sale of Tofte from Norske Skog to Södra. Toftes’ challenge to reduce overall costs by 3 % per year due to falling prices on pulp has thus become even tougher.

What can be interpreted from these figures is that Tofte still has challenges. Besides the two successful workshops, tools like Operator training and the workshops have not given traceable and lasting results thus far. The external demands on Tofte such as effluents limits have become tougher and the demand to reduce costs per produced tonne per year is as important as ever with the current strength of the Norwegian krone. I regard Operator training and Operations workshops as necessary means to improve production, and a tool in order to develop the basic and more advanced knowledge that need to be present. Improvements of these methods are necessary, and these will be discussed in the following sections.

### 7.3.3 Further development of Operator training

In this section, I will firstly discuss how Operator training can be developed in order for it to be a more efficient learning tool.

Experience at Tofte, six years after the Operator training method was introduced by Peterson Linerboard Moss, reveals that this is a demanding task. As can be seen in Tables 6.1 and 7.3, some departments are still not finished after six years.

At strategic levels in a plant frames are given for how fast development can take place. As organising of educational material and writing is an unfamiliar task for most operators, this is experienced to be a more demanding task than expected. What is so far experienced at Tofte is that development of educational material depends upon the individual ORE and the organisation's ability to allocate resources to speed up development. As the OREs have taken the task on besides ordinary work, and there is limited time to develop material within normal working hours on shift, the development will necessarily take some time. Appropriate support, when most of the material (phases) is to be written, is thus necessary. This will also include managerial willingness to let operators be freed from ordinary shift working for a limited period of time. At the drying machines the ORE was freed for three months to work continuously in order to make progress. Alternatively there would be no progress at all. Besides this, they have not been freed. How fast an organisation manages to implement an educational model like OT, is a good indicator of an organisations' ability to learn and also on its redundancy of functions.

Attempts have been made at Tofte to involve more operators, but the extra salary has not been enough. Thus, a vulnerable part of the OT model is the availability and capability of operators responsible for the education. This has, at Tofte, created an imbalance in the different departments (control rooms) with regard to educational possibilities. In those departments with best progress in educational material and conduction, the ORE has, however, made several modifications in the number and organisation of phases. Also, the content has been developed more or less continually as more knowledge and experience is gained.

The latest organisational measure is the Operator training task groups. This is to have a closer control on the structure and content of each of the educational programs and to have more tutors from the control rooms more actively involved. The ORE will now have more time to concentrate on developing material, while experienced colleagues (tutors) do more of the tasks in following up training in the control rooms. Another innovation is that shift management is more directly involved, as they have departments with special responsibility. With this change, more managerial focus is directed towards Operator training. The tutors in

the control rooms are given increased responsibilities regarding education and training of their colleagues. This is consistent with the attempts to give operators more responsibility in general.

Another general change in content is to have more focus on “knowing why” questions in the phases and leave out details that have bogged some programs down. This will, in many cases, require assistance from process engineers and also shift management. This was an initial design criterion, but Tofte practice thus far has shown that this is a necessary change in most programs in order to develop both the Operator training program and Tofte’s process operators.

Operator training is a basic requirement in order to be allowed to operate a department and steps are now taken to focus on each phase in the programmes. In the maintenance of the programmes, how, then, can one build in questions containing incidents or experiences without expanding the basic model too much? An organisational decision regarding this is to have a database on incidents and let the control room teams be responsible for being updated on these.

Development in Operator training can also be made in variance control. In an educational committee meeting, there was a discussion of deviations across departments and control rooms. Two educational responsible operators at the meeting suggested including a phase that informs how deviations from own department influences neighbouring departments. Olsson (1996:14) states, based on Swedish practice, that this is the case:

*“It is necessary in longer directly coupled processes that operators increase the understanding for the whole chain and not just the department for which they are responsible. Operators often have limited understanding for how and why previous processes can cause deviations within own department and how and why this again may influence next department(s). With an increased understanding of these connections, operators will be better prepared for tackling such deviations, increased competence in order to treat deviations optimally from a cost and or process perspective. Increased motivation to not cause difficulties in next department will also be a result.”*

Such a phase within each department should be passed by even the most experienced operators, as some of them never have thought of the problems may cause in other departments or control rooms. It will thus add a more holistic understanding of the entire production process. The techniques of the “variance matrix” may be used in this, and will be performed by and for operators. This suggestion came after one year of Operator training development and the production manager wanted the OREs to finish the development work within their own areas before phases on variances between departments were given special attention. Tables 6.1 and 7.3 give an indication of progress and work remaining after almost six years, based on these figures, the production manager’s analysis would seem to be correct.

Many of the questions made in Operator training are ideal for group discussions in a control room, and may contribute to raise the knowledge level in the entire shift in a control room.

#### 7.3.4 Further development of Operations workshops

Operations workshops satisfy, in theory, all four conditions of a good learning model listed by Ellström (see Chapter 4.4). Tofte practice thus far, however, reveals a big potential for improvement in the various steps of a workshop. In this thesis, I have reported from two successful cases. The remaining eight workshops, that have had a varying degree of success, I have placed in Appendix 8.

Based on the experiences from workshops in the wet pulp department, an inter-disciplinary group from that department in January 99 stated the following:

*“Problem: The task list provided at the end of each workshop is in too little degree followed up.  
Our suggestions for a solution:*

- *An Operations workshop will be arranged when there are enough resources to follow up.*
- *Concentrate the activity on the most important areas that will give biggest effect.*
- *Give process operators responsibilities for activities.”*

These are all central arguments highlighting some of the problems with Operations workshops at Tofte so far. Generally in the organisation, much more consciousness in the use of Operations workshops as method is needed. The following questions have to be raised:



- Why do we arrange workshops?
- What do we need in terms of analyses and preliminary work in order to learn more about the problem(s)?
- Who needs participate in order to solve the problem?
- Are tasks developed in workshops likely to be performed and if so, by whom?

Operations workshops as a method for improvement is demanding, but experience exchange on the method itself between departments at Tofte has thus far rarely taken place. To have experience exchange on best practice can change this matter.

The first question is the central one. The lesson learnt from workshops is that each workshop should focus on only one problem or topic and that those that are most problem-oriented are most likely to succeed. Thus far, management at Tofte have decided when to arrange workshops. However what can be seen in 2002 is that workshops are arranged as results of ideas from the productivity programme. All selected ideas in the productivity programme are on topics that concentrate on the most important areas that will give greatest effect. But again, focused problems have to be chosen in order to improve possibilities for follow up.

The outcome of a workshop very much depends upon how well it is prepared. This includes selecting the problem and how theory regarding this problem is analysed and presented at the workshop. Until now this has been a task at managerial level at Tofte. Process engineers or production management have made all analyses and prepared theoretical contributions. The preparation of a workshop could to a larger degree be tasks performed by process operators in the relevant control room. The responsibility, however, for coordinating the preliminary work must be daytime based.

Who must participate? More focus must be placed on this question as well. When differences in process control practice are the theme, clearly all six shifts should be present. Theoretically 5 shifts can participate at a workshop. It is, however, not ideal to continue after a morning shift (6 a.m.– 2 p.m.) with a workshop. When an important task is to provide a shared practice across all shifts, two workshops on the same theme should be considered at least for very important themes, as a written report, distributed some days after a workshop is no substitute for participation. This was the case in the latest bleach plant workshop, where it was

imperative to teach/inform the operators on the importance of pulp washing in the different bleaching stages. One way to solve the structural constraints given by shift working is to free one representative from each shift such that all shifts are represented and let this representative help the implementation during their shift in the control room.

As task lists have shown, these are often a mix of changed operations and improvements in equipment. Thus all relevant stakeholders also from the daytime organisation need to be present in order to have the cogenerated learning effect and come up with the best solutions.

This design feature is also central when the task list is made. At the end of a workshop the participants must agree upon some criteria on which the workshop can be followed up in order to judge if the workshop has made any difference on operational practice. The passive statement from the wet pulp department in 1999 to not arrange a workshop if there were no resources to follow up, can partly be explained by turnover of process engineers. However, a task list must be realistic, and tasks from a workshop must be seen in relation to other tasks in the relevant department. If a workshop can solve a “problem” then it should have priority and the same with the tasks. More focus needs to be placed on this final activity at the workshop at Tofte. Tasks must be coupled with responsible persons and time limits. The tasks list must also contain dates when task status will be given and by whom. (Feedback is in general identified as a problem at Tofte (IR: Stendal, 1997)). This is especially important when agreements are made in order to try to develop a shared practice. Feedback on results might be lower costs, more stable production with less variance, safer operations and so on. The MOPS information system at Tofte (see Chapter 2.4.6) contains all measured process parameters. A representation of relevant parameters from an OW could be made and easily used to follow up in the control rooms and also as feedback to next OW event within the same control room. This can also be combined with prices in order to see how much is saved by following up a workshop.

Often due to long lag times, there is a need for a control level on a continuous basis alongside the shifts that can trace deviations between shifts so that the reason for the deviation can be captured and feedback can be provided. When regarded as experiential learning, the circle is not closed when the theories are not tested. In the Tofte organisation, this is a task for the process engineer. In order to learn from a workshop it can be necessary that more continuous focus is placed on the theme as the theories and causal inferences are often complex. In some

cases, it also could be worth the effort to repeat theories and practice in a new workshop on the same theme.

Thus far (October 2002), there have been 17 workshops in different departments. With one exception, there were no workshops for four years and thus no occasion to provide feedback on progress from the last workshop in the same department. However with the new initiatives this kind of necessary continuity is more likely to take place. There are good opportunities in closing the learning circle by letting the group tasks in following up of a workshop at the same time serve as preliminary work for the next workshop, or at least to provide status in the next workshop if the problem is resolved and the need for a workshop is elsewhere. This will thus direct the attention of the shift staff to differences in practice between shifts and thus a point of origin to find shifts that deviate and reasons for those deviations. Through this, they are likely to learn in a problem-based manner in order to develop a more correct mental model of the problem at hand. This will, at the same time, show the learning capabilities within a shift in a control room, and managerial assistance can be provided as an aid to develop such learning capabilities.

### 7.3.5 More on organisational and managerial frames for further development of learning arenas

I have, throughout this thesis, argued that more knowledge and skills must be provided to process operators. I have also analysed how two models are developed and utilised as tools in this work. Also, since 1998, a shift-management training programme has been organised. In this, control room team development, has been, and remains, central. Team development is no quick-fix solution in itself. It is nothing more than more concentrated work while on shift. An example of more concentrated work is to follow up the work contract that states that development of educational material is part of the normal work. Participation in Operator training by being an ORE or a tutor is one method. Other methods regarding Operations workshops are to be more involved in preliminary work analyses and in following up tasks from the workshops. Tools are of no use unless they are utilised in a skilled way. A challenge in the control room is to provide those, who, for various reasons, did not attend to the workshop, with insight in order to make them follow up the task lists when these are given. The shift management can act as facilitators of learning by being the link between the learning

arenas external to the control rooms and the important learning that need to take place in the control rooms.

In future productivity work, it is one of the central demands made by Södra that the productivity programme (VHF) shall continue in the line organisation. The structures of the VHF-programme and Operations workshops have many similarities, and Operations workshops have even been conducted as ideas within the programme. There are, however, some structural differences. In the VHF-programme, the ideas have originated from one person or group and have later on been analysed by others. Some weeks or months later the best ideas have been implemented. In a workshop, a task list (i.e. ideas to be executed) is cogenerated and thus the problem-oriented solutions have already been discussed by more relevant parties that are all interested in having this implemented. I have recommended how Operations workshops should be designed and conducted. This form of collaboration and learning by working is in line with the methods in the Swedish model, but improved as a local variant.

In 2003, the Tofte VHF manager cites ten Operations workshops as the goal. While there are still resources available in the programme to develop the method and assist in the different steps of the workshops in 2003, OW could serve as Toftes' variant of productivity work. If this is chosen, there will be more managerial focus on and interest in the method and not least results. As workshops are conducted and evaluated during the year, answers will be given if Tofte has managed to improve the method and thereby find out if Operations workshops are the method for future productivity work at Tofte.



## CHAPTER 8

### CONCLUSIONS

In this chapter I will discuss how this thesis contributes to the literature and to the process industry and universities, and based on this, suggest some areas for further research. Finally, I will, based on my findings, look at implications for what Tofte should do in the future.

#### 8.1 Theoretical contributions

The title of this thesis is “Learning about process control”. Thus, my focus has been on methods of developing knowledge of process control in a continuous chemical pulp mill. The research questions emerged from my co-operation with the Tofte pulp mill and the research programme INPRO, which this study has been a part of. The questions that I developed on the basis of this work are the following:

**What are the learning systems for workers in a process plant?**

**What is the implication for learning of different socio-technical structures?**

And based on experiences from the application of the first two questions at Tofte:

**How can learning be further improved for workers in process industry?**

In the theoretical part of this thesis, I have been concerned with necessary knowledge and skills in operation of a continuous process plant given its features and characteristics. Based on literature reviewed and my insight in the Tofte pulp mill, I have defined a kind of knowledge in operations – process understanding as “**an ability to predict what is going to happen.**” Different kinds of knowledge are all necessary, but more emphasis has to be placed on “knowing why”. In order to further develop process understanding, I also discussed different learning types; experiential, collective, and individual and I discussed the concept of learning arenas using the cogenerative learning model (Greenwood & Levin, 1998) as a means to join the various communities-of-practice in a shift-daytime production organisation.

I also presented design features in socio-technical systems as such whether organisation and management have implications for learning. In the early phases of development of STS (i.e. up to 1966-67), the learning model in STS was a relatively simplistic cybernetic model of feedback control. As STS developed, the socio-technical “school” (e.g., at WRI<sup>59</sup>) moved on to more general approaches to workplace reform (e.g. developing new conference methods for initiating change in the whole enterprise (Emery and Emery, 1974). More specific analysis of conditions and models for learning at work were therefore not carried out. The socio-technical paradigm is based on the redundancy of functions that integrates the democratisation of work life and the economic performance of the organisation (van Beinum, 1988). Redundancy of functions requires multi-skilled persons within a group. Thus, in the new paradigm, knowledge and learning capacity on the shop-floor is an important requirement. STS provides frames and direction for learning to take place within groups along the production line. It is, however, not within the scope of the STS paradigm to provide theories of what constitutes knowledge in the operations of a plant. And STS- theories are not developed in order to cover specific models of how learning within and across semi-autonomous units and organisational levels may take place.

Thus, the main contribution of this thesis is learning theories based on two different kinds of learning models as means to develop process understanding. These are Operator training and Operations workshops. Ellström (1996:28) makes a difference between adapting directed and developing directed forms of learning. He claims that future forms of learning should be more developing directed. Such a methodology allows “systems” to:

- *Perform work tasks related to the whole system*
- *Formulate a problem, analyse its origin and how it may be solved*
- *Critically judge measured values and take proper action*
- *Take responsibility for a larger area or processes*

In this thesis, I have shown that the two learning models aim to fulfil the criteria to be a form of developing directed learning. The strengths of the methods are found in the collective learning that takes place in cogenerated learning arenas where different communities-of-

---

<sup>59</sup> WRI-Work Research Institute in Oslo.

practice meet. In Operator training, this strengthens the master-apprentice method in control rooms, and in Operations workshops it can give a more shared understanding and direction for further tasks in process control. A goal of socio-technical system design is to make control rooms more autonomous or independent. Learning arenas can also be regarded as tools in making the control rooms more independent. The control room community-of-practice is the most important learning arena, as this is the place where theories are tried in practice and new practice is transformed into new theories. Operations workshops are examples of problem based experiential learning and thus cogenerated variance control.

By developing and using Operator training and Operations workshops, I have shown how these models enable managers to become better facilitators for learning, as they have structures where they can be regarded as the “outsider” in the cogenerated learning model. The challenge identified at Tofte, which is one of cooperation and responsibility distribution regarding the education and training of apprentices and operators, is to a large degree resolved.

Both in Operator training and in Operations workshops, operators’ knowledge and skills are important. Thus, these learning models will also be a help to better utilise educated operators’ knowledge and skills in the future and at the same time provide more challenging tasks as learning is combined with working and development of the plant.

STSD is a requirement for developing directed learning to take place in the control rooms. Operator training and Operations workshops are necessary tools both to provide “knowing why” and to be a means for variance control, and also tools where operators are entrusted with important tasks in the development of the plant.

When looking at Operator training, I have shown that it is still too early to conclude anything about its impact on the results of the pulp mill. However, as educational system in a continuous process plant, it has made a positive contribution. Two Operations workshops have made positive contributions and demonstrated the potential of this method in variance control. The other workshops have, for various reasons, not been followed up and the learning effect cannot thereby be checked.



### 8.1.1 Contributions to Tofte and process industry

The Operator training model was originally developed at Peterson Linerboard Moss. They shared their model with Tofte and I have described the structure of the model and how it was implemented at Tofte. I have discussed how such a model is useful in improved utilisation of operators' knowledge and skills and how it structures educational tasks between production management and operators. The descriptions given in Chapter 6 can be adopted for use in other process plants as well, as this model is by no means restricted to pulp mills.

The other learning arena; Operations workshop has also proven to have positive effects, as this model combines problem-based learning with productivity efforts. I have given the structure of such workshops, and experiences of how Tofte has used them and the results that Tofte have achieved. I have also discussed the critical factors involved in the success of such workshops. This way of integrating problem-based learning with productivity increasing measures, can be strongly recommended to other process plants.

## **8.2 The need for further research and development**

I was inspired to learn about my research questions by an action research strategy and, at the same time I participated in the development of learning arenas. My contribution to the academic literature is therefore a thesis where I have tried to combine action in the development of learning arenas in a process plant with research on how I learned about these arenas and their effects.

I also started data collection and analysis in a third learning arena; project participation. I chose to leave out this since proper treatment of this topic would require a thesis on its own. Levin (1995) argues that: "*Technology development is organisation development.*" In line with this, technology development in plant modifications can be organised as learning arenas, and as such, as organisation development. This topic lies open for further investigation and is also well suited for action research as the researcher would be a welcome resource in arranging arenas and would at the same time report from the arenas and feed the findings into the ongoing project in order to ensure that the users are familiar with the new equipment and that operations and design are integrated (ref. Husemoen, 1997).

A more focused study can also be made on one or more Operations workshops. A researcher can also take an active role in the workshops and help the organisation to structure results and report back in order to improve the model and/or implement it in other departments in the same organisation. Operations workshops can also be used between departments in order to detect variances between these. A researcher can then be a helpful resource in an organisation to bridge between two departments and learn more about the method as variance control and educational method.

Also, in Operator training, it would be interesting to carry out a more focused study. The researcher could benefit from concentration on one department, measuring changes in process understanding and specific results in the department.

### **8.3 Recommended action for Tofte**

Tofte has, since 1996, developed and used Operator training and Operations workshops as learning models. Educational material for Operator training has taken long time to develop, and a few departments are still not finished with this task even after six years. This has been due to lack of available resources in a demanding workplace. An organisational change was made in 2002 with the establishment of educational task groups for each department. A shift manager has the responsibility for each group and through this, shift management is more directly involved in the development of training programs and the development of the operators. The task groups will also consider the content more critically in each programme and make necessary changes in direction to achieve increasing process understanding by having more “knowing why” questions.

Operator training is regarded as basic training for apprentices and operators learning a new department. Experiences of failures or serious deviations can be analysed and recorded and used in a programme for control rooms for more experienced operators. Also, more experienced operators could benefit from working with various questions in the program. This is, to some degree, already accomplished through the tutor programme. Recommended action at Tofte is, then, to keep managerial focus on the programmes in order to complete them and modify them where necessary. The most important design feature is the central tasks process

operators have and the combination of working with learning. The process operators need to be entrusted with central tasks in the development process, and management must continue and be aware of their role as facilitators for learning.

Operations workshops at Tofte have on two occasions proven their efficiency. Besides this, other workshops have, for various reasons failed. In this thesis, I have recommended Operations workshops as pedagogical method as it combines collective learning with experiential problem-based learning, and finally individual learning. For the Tofte organisation this has proven to be demanding and often too demanding.

My recommendation for Tofte is thus to continue this kind of work, as Tofte has no choice but to become more cost efficient. Experiences from this thesis work have revealed that much more consciousness of the use of Operations workshops as method is needed generally in the organisation, and the following questions need to be raised:

- Why do we arrange workshops?
- What do we need in terms of analyses and preliminary work in order to learn more about the problem(s)?
- Who needs to participate in order to solve the problem?
- Are tasks developed in workshops likely to be performed and if so, by whom?

As Tofte also focuses on teambuilding in the control rooms, specific tasks are needed in order to be conscious of developmental tasks. Both the following up of workshops and analyses for new workshops should be considered as such tasks. Tofte also has obligations to integrate the ongoing productivity programme in the line organisation. Operations workshops can be a tool for Tofte to test in the coming year, as resources will be present in the productivity program to learn more about the method and how it can be regarded as developing oriented learning.

## **APPENDIX**

### **A1. INPRO**

INPRO (INtegrated PROduction systems for the process industry) is a multidisciplinary initiative at the Norwegian University of Science and Technology. Its goal is to develop expertise to give Norway a leading position in the effective operation of process plants.

The INPRO program is designed as a PhD programme, where each student relates to one specific company. A central idea in the program is to link solutions of concrete and important issues at company-level with in depth research. The program is action oriented aiming at creating scientifically relevant knowledge by solving pertinent problems. By applying a multi-perspective frame, which includes the organisation and leadership, cybernetic, and chemical engineering perspective, new and comprehensive solutions to real life problems are sought. The main challenge is understanding the operation of process plants as a complex engineering, economic and organisational systems, and to develop solutions based on holistic understanding.

The INPRO- program is funded by the Norwegian Science Foundation, Federation of Norwegian Process and Manufacturing Industries (PIL), The Norwegian Oil Industry Association (OLF) and participating companies.

The program, with 9 companies and 9 PhD students, officially began on 1 September 1994. Five students attended the Department of Organisation and Work Science (ORAL), two attended the Department of Engineering Cybernetics (Cyb) and two attended the Department of Chemical Engineering (Chem).

The participating companies are (with student department in parenthesis):

Hydro Aluminium Sunndal (ORAL)

Borregaard ChemCell (Chem)

Statoil U&P, Gullfaks (ORAL)

Statoil Research Centre, Trondheim (Chem)

Elkem Corporation (ORAL)

Falconbridge Nikkelverk (cyb)

Nycomed Imaging (Cyb)

Phillips Petroleum Norge (ORAL)

Södra Cell Tofte (ORAL)

The programme was officially closed in January 1998; 5 out of 9 theses have been completed and defended during 1999.

### Objectives of the program

The aim of the INPRO programme is to carry out multidimensional research on the operation of process plants, graduate a group of highly qualified PhD students, and to create a graduate degree focusing on the operation of process plants.

The programme can be divided in the following main task areas:

- Graduate PhD candidates with a comprehensive understanding of complex production systems.
- Develop multidisciplinary expertise at the NTNU, to provide knowledge to Norwegian process industry.
- Develop a graduate degree dealing with the operation of process plants.
- Develop expertise within Norwegian process industry in dialogue with the engineering school, enabling continual and multidisciplinary approaches to effective operation of process plants.



### **A3. The trade certificate**

Three theoretical courses are offered:

1. A basic-level technical course covering the basic tenets of mathematics, chemistry, and some physics. These courses are mostly for adults that need to be refreshed or have not covered the topics in school/college. A requirement for being accepted as an apprentice is to have covered this through secondary school/college.
2. An industry-specific course covering all main aspects and main transformation theories within the given industry. This gives the operators a holistic perspective of the value chain and explains how and where their learning area (department(s)) fits into the production chain.
3. Process control. A course covering controllers, valves, valve characteristics, positioners, lag times, dynamics, different control modes, and other aspects regarded as necessary in order to master the process.

All courses are a combination of local education normally given at a weekly meeting during the autumn and winter and a weekly letter (ca. 20) that is passed to PIL centrally where it is commented upon and given a mark. Each course ends with an exam. Since the courses are given by local instructors at the plants, local conditions will be used to exemplify different topics. The “students”, thereby, have a possibility to recognise given theories and situations from practice and thereby transform given information into knowledge more easily. The courses are given in parallel to ordinary shift-work both for §20-candidates and for apprentices.

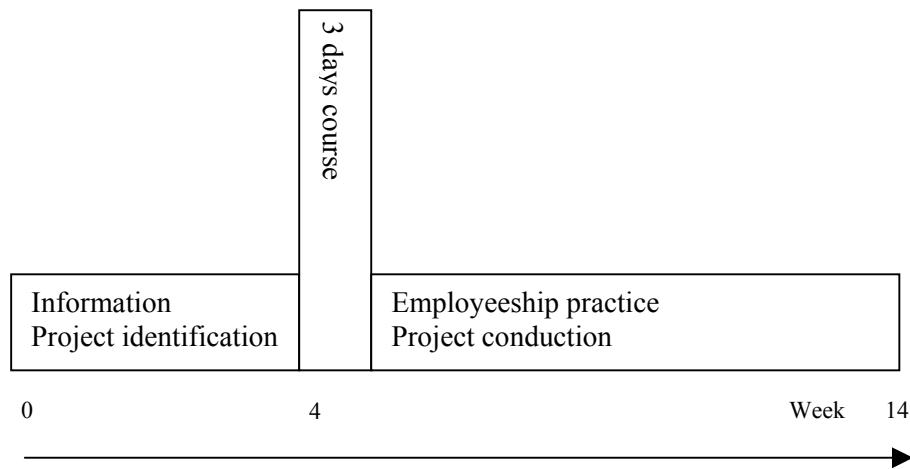
After a Norwegian education reform called “Reform 94”, an apprentice must in order to be accepted, have completed two years after secondary school with emphasis on mathematics, chemistry, and physics. The apprenticeship learning period at a plant is estimated at two years. Given that all courses are passed, this learning period will terminate with trade certificate examination which is a combination of both theoretical process understanding and

practical skills (such as, e.g., being able to start a plant). The trade certificate must, however, be regarded as a step towards becoming skilled, and not as a final exam.



## A4. Employeeship

The original model can be seen in the following figure:



**Figure A4.1 Original Employeeship model**

First step consists of self-reflection exercises. A booklet with questions is distributed at the first meeting where the course group members meet for the first time. In functionally divided plants, many people do not know each other. A main point with the Employeeship courses is, therefore, to have a vertical and horizontal mix of organisational members at each course. During four weeks the group members are supposed to identify projects which they can conduct after the course in order to practice the theory when it is still fresh. This project period is estimated to last ca. 10 weeks.

The courses that last for three days are held at an external site have the following content:

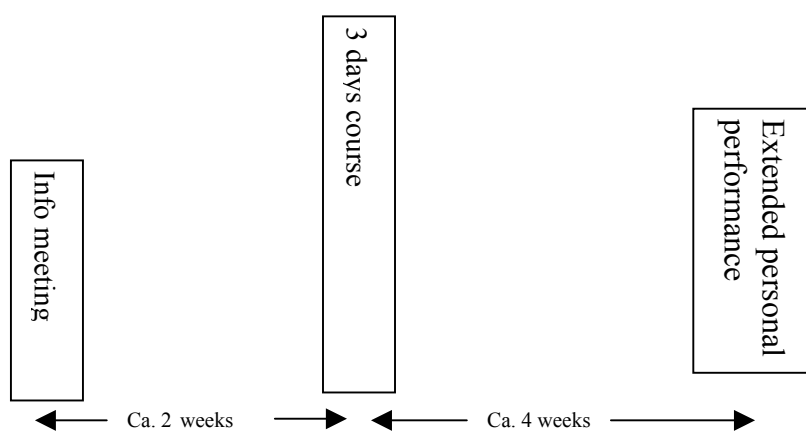
- Plenitude gives strength
- (Self)-insight
- Management
- Business strategy
- Learning organisation
- Culture
- Communication
- Change
- Behaviour
- Groups

The work done at the courses is a mix of theory and application. Group techniques such as brainstorming are used to a great extent. In the original Swedish model it was also stated as important that resources from the organisation should be responsible for conducting the courses, as they could later serve as agents for internal change.

### The Tofte model

At an Employeeship project meeting in December 1995, B. Rasmusson (the Swedish founder), three Norwegian consultants who would be responsible for most of the execution of the courses, staff from the organisation and personnel department at Tofte, the union leader, and the IT manager were gathered to go through the original content and adapt it to Tofte<sup>60</sup>. This meeting lasted three days. At the end of day three, important decisions were made about how Tofte would conduct the courses.

Tofte ended up with the following model:



**Figure A4.2 The Employeeship model at Tofte**

<sup>60</sup> At this time it was decided that I would have a leave from the INPRO-project and follow the Employeeship project on a full time basis as a researcher. I was therefore also present at the meeting and took part in discussions.

With this model, Tofte wanted to achieve the following main and sub-goals:

Main goal: Make a foundation to a more effective and changeable organisation

Sub goals:

- Self insight
- Responsibility for own development
- Better understanding of Tofte's goals, strategy and organisational principles
- Create better opportunities to utilise the competence

The main deviation from the original model was that Tofte chose not to pre plan any course-related projects and thus implement the theories. The main explanation for this was that more projects would take too many resources and was not realistic. The project could therefore fail. The alternative was to apply the theories from the courses into daily practice and existing projects<sup>61</sup>. It was also decided that the external consultants would be in charge of conducting most courses. Tofte's main follow up activity would be an extended personal performance review within 4 weeks after the course. Each employee was supposed to make a personal action plan prior to this conversation. The last chapter in the course book was written by the Tofte project leader. In this he wrote:

*“...we also have to bring theories and responsibility into existing projects and into methods of performing work. ...That much focuses on plenitude and responsibility, means that we, in the future, will work differently to the way we work today. We think of development of educational material and inter-disciplinary teams will perform other concrete challenges. This, we believe, is a prerequisite for building a more changeable organisation” (IR. Medarbejderskap, 1996).*

---

<sup>61</sup>I argued against this model since I believed that Tofte didn't follow through. I feared that the people responsible for follow up activities were not dedicated and the project could fade out. However, the arguments that won were fair enough, they re-emphasized one of Tofte's major problems - time and dedication to interdisciplinary work and cooperation.

## **A5. Interdependencies between “operations” and “maintenance”**

In functionally divided organisations, operations and maintenance are separated in different departments. Sophisticated technologies, requirements for authorised certificates, and the need for personnel who are highly skilled in numerous technologies, will in many cases make a certain functional distinction necessary. In practical operation, however, there exist no sharp divide between operation and maintenance.

Typical operations will be monitoring and adjusting the processes via the computerised information systems from a control room, while typical maintenance is thought of as repair of equipment that has failed or is about to fail. However, there are tasks that cannot be placed entirely within one of these systems. This was also one of the findings in a socio-technical analysis made at the Hydro fertiliser plant in 1967. Emery & Thorsrud, (1976) suggested that various kinds of repair work were significant parts of the daily workload throughout the factory and it proved to be difficult to separate maintenance from normal process operations. Since there is seldom any redundant equipment that can be repaired during production in a one-line system, high capacity and stable production requires the different equipment to be functioning all the time. Systems and practice regarding preventive maintenance are therefore of vital importance in a plant. This put extra pressure on both maintenance routines and the performance of the repair work.

Despite systems for preventive maintenance, including non-destructive testing, some equipment will, from time to time, fail. Decisions and priorities regarding maintenance are therefore a major task in all process plants and these challenge the co-operation between operations and maintenance. How does a failure affect production? Will production be reduced, will the quality of final product be affected, will the department have to be operated differently, how long will a repair take and can it be done during normal operations? These are typical questions that arise daily. Another complicating factor is that it is not always clear-cut what comes first: operational conditions leading to a mechanical failure or a failure leading to operational problems. Since unit operations often are enclosed and integrated, inspections often will require a full stop in the department. Thus the hen and egg metaphor is often used in operations. This can be illustrated with an example. In a vapourisation unit<sup>62</sup> a

---

<sup>62</sup> In the Tofte pulp mill.

large drop in pressure was experienced and this reduced overall capacity. It was expected that this was due to growing in tubes and corrective actions were taken. These did not help, and an inspection required a full stop of the department and also a complete plant stop (the unit had to be pressure-less and cool and also extensively cleaned). When the unit was finally opened, it was detected that a droplet collector device had fallen down and obstructed circulation. This could be recognised as a clear mechanical failure, but why this failure after many years in operation? Was it due to changed operational conditions such as more corrosive chemicals, thermal expansions due to too rapid start up, or could it be vibrations due to too high throughput?

Other features connecting operations and maintenance are matters of health and safety. In transformation processes, high temperatures and pressures are common and often large quantities of thermal energy are stored. In addition to this comes the use and production of hazardous gases and liquids, which demands special attention from production personnel. In order to avoid dangerous situations, sound operational practice has to be performed by all involved. There is a need for extra precautions in order to avoid an accident during unstable situations when maintenance is required and the interruption of production is limited by segregating sections of the equipment that have to be repaired. Workers may get hurt if they do not pay enough respect for the dangerous chemicals normally kept well inside the process equipment.

More generally; Process operators need knowledge of how their operations affect the equipment in use. It is therefore important to know how the various production equipment is constructed and to know which critical parts may malfunction if subjected to improper operation. Whenever maintenance is required, the process operators have to prepare relevant equipment for inspection and necessary repair and to find the best solutions to produce optimally while maintenance is performed. Maintenance personnel need knowledge of what is going on inside the equipment in order to inspect and maintain safely and to be able to communicate to the operators how equipment may be modified or how operational practice can be improved.

## **A6. Features and characteristics of a continuous process plant**

- One main production line, no redundancy of main equipment
- One main product (pulp, aluminium, silicium, etc.), but can have different qualities
- Often many different production technologies within one plant
- Capital intensive, requiring maximum capacity utilisation
- Complex interactions between different process equipment and departments (feedback)
- Disturbances spread quickly up and down the production line(s), requiring rapid corrective action (decision making through hierarchy is inefficient)
- Different technologies are spread over large areas
- A continuous plant requires manning 24 hours a day, 7 days a week
- Variance control is a central task
- Production can be divided into two main phases: continuous production and stop situations
- Production experience is gathered in routines and procedures
- Systems are often fully automated with only minor physical interventions or direct work on the processes
- Most transformations take place in enclosed equipment.
- The control room(s) is/are computerised
- Different kinds of process control which may be demanding to understand
- There are strong, direct dependencies between the tasks/functions along the production lines, and between “operations” and “maintenance”
- Some processes are poorly understood and described
- Representations of the process departments and plant are required
- Good maintenance practices needed, including preventive maintenance
- Managing the control and problem solving tasks normally requires the involvement of persons with different skills and professional backgrounds
- For technological reasons, continuous process plants are conducive to decentralised, integrated, team based forms of work organisation

## A7. Aspects in variance control

A key task in operations is process or variance control. Process control takes place at different levels within an organisation and with more and less direct human interaction with the processes. Process control of a plant can therefore be characterised as interaction between the technical and the social systems. Process dynamics and process control, where use of feedback control loops are most common, has to be understood as well. How the processes respond to changes imposed by operators and how time lags can cause uncontrollable variations must be a part of an operator's knowledge base. Degree of automation is dependent upon how well processes are understood and explicitly described. Metal furnaces, pulp digesters and recovery boilers (in pulp industry) are examples of complex dynamic systems that are not fully understood or, thereby, described and are thus automatically controlled. Even though technological improvements are made, according to Hirshorn (1984:157)

*"...the notion of total machine control is false. As we have seen, engineers have not attained the necessary technical and mathematical understanding of complex production processes to develop comprehensive control systems- systems that can keep cost, volume and quality at optimum levels. The production processes are hard to model, many relationships between crucial variables are only intuitively understood, and engineers cannot predict how extreme values of certain ambient conditions such as the quality of raw materials might change variables within the production process."*

Despite improvements in automated control, there is a need for competent personnel.

Pasmore (1988:62-65) has developed a list of general socio-technical design features of a plant:

1. Variances should be controlled at their source. Unexpected deviations from standard operating procedures, plans or normal routines, represent unanticipated or uncontrolled problems in conversing processes. Typically, these variances result from the inability on the part of employees to either: a) identify the conditions which cause variances to occur; or b) take actions to correct conditions that are likely to lead to variances occurring once such conditions are identified.

2. Boundaries between units should be drawn to facilitate variance control. When variance control within a single step or sub-operation of the conversion process is impossible due to interdependencies with other steps or operations, boundaries of the system should be drawn to include the interdependent units in the same department in order to facilitate the identification and correction of variances.
3. Feedback systems should be as complex as the variances, which need to be controlled. In technical systems, variance control requires a system that is capable of detecting variances that may occur, even though infrequent and unanticipated. The trick, obviously, is to design an information system, which is capable of anticipating the unanticipated so that employees may detect and respond to variances before they cause major disruptions in the system.
4. Inputs should be monitored as carefully as outputs. The success of the conversion process depends on the quality of incoming resources –in this sense meaning more than raw materials; the quality of technology, employees, managers, and support systems all affect the outcomes of the conversion process.
5. Core absorbs support. ... The separation of core and support functions are often taken too far; Bureaucratic barriers are created which interfere with the ability of the core operations to obtain the support they need when they need it. By reuniting core and support functions, adjustments to variances can be carried out more expeditiously. In addition, the jobs created by combining core and support functions tend to be more complete, varied, more demanding of skills and hence, more motivating.



## **A8. 8 Operations workshops**

In this appendix, 8 Operations workshops are described and analysed. They are placed in the appendix in order to make the thesis more readable. The 8 workshops in this appendix are however central when Tofte's ability to utilise the workshops is discussed.

### **Recovery department. The first workshop**

The first workshop of this kind<sup>63</sup> was initiated by two process engineers in the recovery department. As process engineers, their tasks were to write operational routines and procedures according to ISO certification. They also had responsibility for checking lists to be used in stop- and start situations. This was time consuming and thereby difficult for the engineers to carry out. One problem with writing for others can be illustrated with the following quote:

*“For one shift I made a routine and got feedback from their shift manager that it was too detailed. I then removed details that resulted in the shift using one hour to search for the right pump, but I guess they learnt a lot from the search.”*

They thus meant it was more natural if the operators themselves described their own practice and used a language and degree of details in routines and procedures with which they were familiar. Various strategies were discussed at the meeting, and proposals were made about how to distribute the tasks between the different shifts.

The operators were satisfied with this kind of dialogue and the allocation of tasks between shift and the engineers. They also recommended this way of working to colleagues not present. The process engineers served as co-ordinators, as different groups made progress in writing the routines. By the end of 1998, good progress has been made and operators are still active in the development and maintenance of routines and check lists.

---

<sup>63</sup> Various meetings consisting of shifts and daytime employees have also been arranged earlier at Tofte. This meeting, however, was the first where the concept Operations workshop was used and techniques from the Employeeship courses utilized.

### The drying machine workshop

Encouraged by the two earlier workshops that were, by many regarded as successful, the turn of drying machine no. 3 has come, as Tofte experienced severe losses in this part of the pulp process. See Table A8.1 which shows total losses due to the drying machine. Thus the topic was to increase capacity utilisation by improving the practice of getting the pulp web through the machine after a web-rupture.

**Table A8.1 Capacity utilisation drying machine 3**

	1994	1995	1996	1997	1998	1999
Rupture, tonnes	2,416	3,972	6,388	8,628	7,492	2,864
Guide rope, tonnes				2,138	1,801	316
Rolls, thickener, etc., tonnes	400	1,487	1,362	2,753	4,538	2,518
Bailing and wrapping, tonnes						10,544
Sum, prod. Losses, tonnes	2,816	5,459	7,700	13,519	13,831	16,244
% of max cont. capacity	0.7	1.3	2.0	2.9	3.1	3.4

The process engineer in charge of the workshop regarded it as successful up to the point where the operators were to should make priorities and agree about primary causes and effects. The operators had difficulties in changing from a problem-oriented mode to a solution-oriented mode. At this workshop they did not manage to come to any agreement, and the attendees left rather disappointed and frustrated, as all had hoped that the workshop could help to reduce the production problems<sup>64</sup>.

As can be seen in Table A8.1, the problems became more severe in 1997. Even though this specific workshop was regarded as unsuccessful, it left some valuable experiences. These were collected in the minutes of meeting and also in a report written by the process engineer in PIL's basic management course (Ledelse 1):

- A workshop is not automatically a success: -they were too optimistic on behalf of the method itself.
- The problems they tried to solve were too many and complex to be solved during one workshop. They did not manage to focus on one problem area, which resulted in too little time to prioritise the different suggestions at the end of the workshop.

<sup>64</sup> In addition to reduced capacity utilisation, rupture in the pulp web and difficulties with getting started require hard physical work in a warm area.

- It should have been made concrete how to conduct short term and long term measures. Action plans with responsible persons and time limits were wanted.
- The fear was voiced that “this would be another meeting with nice words and no action.”
- Because of the negative development, the drying machine no. 3 will be given special attention in a specific project during 1998.

The plans for this project were presented at an Employeeship follow up seminar in November 97. In this project where technological improvements as well as operational practice are important, smaller groups will be used to develop operational procedures for distinct parts of the drying machine. These procedures will then form basis for more focused workshops. However, progress with the groups has also been slow, and by the end of 1998, there were still challenges relating to operations and maintenance to be coped with.

### **The bark/oil workshop**

Bark from spruce and pine is removed from the logs in the wood department. From a buffer storage unit, it is pressed in two parallel presses in order to remove water and transported on conveyor belts to a bark boiler where it is burnt and thus provides valuable energy in the plant. At the workshop, while there was potential for a good level of participation, since operators from two control rooms were invited, only three participated, and only one of these came from the department where the problems originate. In a brainstorming session, the main problems were related to quantity and quality of the bark.

The major quality problem is the water content in the bark; water is added in the debarking drum, and the bark is pressed before transport to the boiler. The availability of the two presses is too low and additional oil in burners may be used in order to destroy the bark.

The following points are taken from the task list:

- Common operational practice in the boiling house
- Exchange of boiler house and wood operators
- Improved maintenance of bark presses
- Alarms linking bark system to the boiler house

The effect of the workshop, by bringing two departments together, were minor due to too few operators attending. A higher managerial attendance gave a better shared understanding of the control problems, but it is not possible to detect any improvements in practice as a result of this workshop.

The production manager also wanted to have practice regarding the water purification plant on the agenda. The topic was prepared, but there was no time left, thus a lesson learned was to focus on one theme per workshop.

### **Chlorine dioxide plant**

Tofte produces the bleaching chemical chlorine dioxide ( $\text{ClO}_2$ ) in a separate plant. It is controlled by the same operator who is responsible for the bleaching processes. The direct background for holding the workshop was a minor explosion that happened in summer of 1997 after an interruption of the power supply. No persons were injured, and the consequences were not extensive and the plant could be restarted 10 hours later. The main focus of the workshop was safety considerations as operators and maintenance staff felt unsafe by being in the building.

From the minute of meeting dated 971112:

*“ $\text{ClO}_2$  is an unstable chemical.  $\text{ClO}_2$  is a chemical that should be treated with respect. To feel safe about its production, it is important to understand what can take place and why. We want a department where nobody should feel unsafe, and where the necessary knowledge is present to tackle most eventualities.”*

After presentations of analyses made by consultants and internal inquires the attendees were divided in four groups and asked to make a “top 5” list of measures to improve safety.

According to the process engineer in the department, it was an easy task to find what the groups had in common, and what should be of priority. The list contains a truly integrated blend of redesign and modifications of process equipment (mechanically, electrically, and instrumentationally), new routines, and the need for better process understanding through education and upgrading of the process flow sheet.

Regarding education, the following points were given in the report: repetition, experience exchange, and then a new operations workshop. The education can be covered by the Operator training when this is completed (1st revision) in 1998. The mechanical removal of all unnecessary equipment is accomplished. Routines of washing the reactor repeatedly every 14. day are imposed in order to improve safety. A projected safety system is also installed in accordance with the task list. The process engineer in the department argues that attention on the department has increased after the workshop and he notices that an increase in process understanding has taken place by the kinds of questions the operators ask.

At the end of the workshop, a group of volunteers was selected to form a project group to work out the details from the workshop. Resources have been used, both money and a project engineer, to implement the improvements. The project engineer was present at the workshop and thereby got first hand information about what the process operators meant should be prioritised. There have, however, not been any meetings of this group. A new follow up workshop was planned to occur before 1 March 1998, but this did not take place. (Next workshop in this department was in March 2002). Thus the production staff did not receive feedback on realisation of tasks.

### **The gas treatment workshop**

The background for the workshop is taken from the report:

*“During the last years the lime kiln has stopped three times yearly in order to repair insulating bricks. Each failure costs between NOK 2.5 and 3 million. We often get foaming in the stripper in addition to other production problems. The last event with big amounts of condensate direct into the lime kiln almost dismantled the coolers of the burnt lime.”*

This workshop brought together operators from two control rooms, the continuous digester and vaporisation/causticizing which also includes the odorous gas treatment plant. Thus an aspect of this workshop was the bringing together of operators from the department where problems originate and the department that has to react before the consequences become too severe. Turpentine is a by-product of the digesting process and this product is normally sold. The problem at stake at this workshop was that some turpentine as liquid had escaped from

the digester area and followed the gas pipe down to the recovery department where it was finally fed into the lime kiln and caused extensive fluctuations in the fire zone area. The problems from such deviations are discussed under the “lime kiln workshop” in Chapter 6.3.3.

This workshop was poorly prepared, but the OT responsible operator from the wet pulp area had good local knowledge and “saved” the workshop by showing flow-sheets in order to identify possible causes. The workshop was about how to better control uncontrolled feed of liquid turpentine in the gas system and many interesting theories emerged. It also served to inform the digester operators about consequences in the recovery department and vice versa how and where such disturbances arise. It was not a question that turpentine had appeared in the lime kiln, but more how it was at all possible.

The problems originate in the pin chip digester. This unit had a low capacity utilisation and is often stopped and restarted. When it starts, large amounts of air (non-condensable gases) are sent into the gas system which is not dimensioned for such amounts. Deposits in a gas scrubber was detected as another main problem area.

From the discussion of how future problems could be avoided, a task list was made. This included already decided process system changes at the pin chip digester, and new operational routines of which one was reprogrammed in the advanced control mode. The task list also included the disposal of information from the digester to the lime kiln operator in case of deviation and when the pin chip digester is started. Some physical modifications were performed, but the task is complex and involves newly installed process equipment, and there are still too many deviations. However, based on the workshop where operators from two of six shifts attended from the wet pulp department, more information is provided to the liquor operator due to new knowledge of possible consequences.

### **Bleach plant workshop**

The aim was to optimise the bleach plant with regard to the consumption of the bleaching chemical chlorine dioxide. The process engineer had made a thorough analysis of Tofte bleaching results as input for the workshop. Also as an introduction, theory of bleaching and consequences on effluents were presented by the research department manager. Thus the theory was to be used in the later discussion of how to optimise the bleach plant.

The participants were divided into three groups, and the results were presented and discussed in plenary. The analyses from the process engineer had shown that Tofte practice was not too bad. However, several practical proposals resulted from the discussion, with suggestions for optimisations. The proposals showed good insight and a wish to utilise the knowledge in improved production.

Emphasis was made on the importance of reducing the kappa variations from the digesters and good washing of the pulp before entering the bleach plant. This will give less variation in bleaching results and improve quality. A constant temperature of hot water to the bleach plant was also emphasised and this had to be focused upon to a greater extent. Much emphasis was also put on measurement devices; a demand came from operators that the kappa analyser functioned, if not, stopping the bleach plant should be considered in order to repair the analyser.

Besides the learning that took place at the workshop, themes from the workshop have not been systematically followed up by operators or by the department. It was stated by a shift that was well represented at the workshop that:

*“We need a longer time horizon than the 8 hour shift in order to follow up parameters. When the residence time through the bleach plant is 10 hours, it is nice to know the end result before parameters are changed.”*

### **Pin chip digester workshop**

The focus for this workshop was to increase the capacity utilisation and reduce variance in kappa numbers (quality measure). As discussed in the gas (turpentine) workshop, a higher capacity utilisation (more stable production) is the best means to reduce disturbances in the gas system.

This workshop followed much of the same pattern as the bleach plant workshop. Here, the production manager gave a theory lecture on how process variables influence the product quality. In the pin chip digester, the kappa number is a function of residence time and temperature. It was documented that the kappa number varies too much and thus these variations have to be minimised.

Three groups discussed suggestions on a predefined list of problems.

Focus was placed on:

- Various equipment that had to be modified
- A more stable feed of pin chips
- Improved temperature control
- Theory to connect operations with product quality.

This workshop came in a period of activity for the department. There was also a change of process engineers just after the workshop. The task list has not been followed up, and there are still large fluctuations in kappa number. Most of the tasks from the workshop are, however, still valid, thus a new problem analysis is not necessary.

### **The wood department workshop**

The theme at this workshop was identification of production bottlenecks and suggestions for improvements. This department has not been in managerial focus for quite some time. As long as enough chips are delivered to the correct chip piles, the operators have, to a large degree, been left to themselves.

Increased production means that more wood has to be handled by the department. The new homogenisation chip pile also requires a continuous feed in order to obtain maximum homogenisation effect. After a reorganisation in 1998, this department was merged with the recovery department and thus put more into managerial focus. 14 operators turned up at the workshop and made suggestions for improvements. All suggestions were directed against equipment and not operational practice. Three months after the workshop, none of the suggested changes are affected, but according to the process engineer, the task list and the priorities given will be followed by the department.



### **The recovery boiler attempt**

This last example is not regarded as an operational workshop as it does not fully follow the model provided in Figure 6.2. However, it highlights some topics and difficulties posed by different practice between shifts and when operators attempt to solve them.

In a telephone call I had with an operator in the recovery boiler department about the practices after a successful change project of the control systems, I asked if the operational practice between the different shifts had been improved. He could not answer yes to that question, but we began to discuss the matter and he came up with several points. I then asked him if he would write down what he had told me and send the note to his shift manager and the department managers that are in charge of optimisation development. Before the letter was sent, I was consulted. Here is what was he written:

**“Case: Further development of combustion at the recovery boiler”**

*If we are to operate the recover boiler optimally, we have to align the operators' competencies. From this, we have good experience from the work we did in making the control pictures on ABB Advant.*

*My suggestion is: Workgroup, competence development.*

*Each shift selects an operator to join the work group. The first meeting will be for orientation and discussion about status and what our goals are. If we are to progress with optimal utilisation of the recovery boiler, we have to agree upon the way we operate it. We almost agree, but are we good enough in following each other up?*

*From time to time many changes are made at the same time, so that it becomes difficult to judge whether these have positive or negative outcome. There are many things to grasp here, as for example the state of the black liquor, how it behaves in the vaporisation department.*

- *Water content, viscosity, temperature, content of organic/inorganic*
- *Liquor spread's position in relation to the liquor*
- *The size of the bed, combustion, degree of reduction*

- *Combustion air distribution (in % and amount) excess oxygen, carbon monoxide, carry over, dust*
- *Temperature of emission gases.*”

I encouraged him to send it as it was and emphasised the importance of the fact that this initiative came from the operators, who are the only ones who operate the boiler. I also referred to a conversation I had with the production manager: that this initiative was in line with his wishes and that this move would have his support. The department management had also been under pressure to facilitate optimisation for some time.

Five operators representing four shifts met with the department manager, the process engineer and myself. The chemistry and processes in a recovery boiler are very complex, and therefore hard to model and understand. This is a main factor for different representations. It was confirmed at the meeting by at least two operators that they had 6 or even 12 different operational philosophies.

The main disturbance is the black liquor, as both amount and composition vary. Production of short fibre and long fibre pulp produces black liquors with different properties. Little systematic knowledge of black liquor composition and properties exist. In the last years, the boiler has been easier to control with short fibre liquor than with long fibre liquor. The main concern has been to get smooth output with smelt from the bottom of the boiler. It has caused minor explosions when the smelt suddenly appears and also causes problems with gasses and fumes.

Plugged smelt openings from the bottom of the recovery boiler that have to be opened manually by the operator due to highly viscous smelt have been the main problem. Ideally the smelt will flow easily into the smelt dissolver.

At the meeting a list of priorities were made:

1. Smelt properties
2. Have a low and constant smelt bed level
3. Degree of reduction (one of the main desired reactions from sulphate to sulphide)
4. Dust emissions (within permitted limits)

That all of the attending operators have long experience and a good process understanding of causes and effects was demonstrated when the different theories were discussed. The importance of keeping the bed at a specified level and not allowing it to grow, turned out as a basic principle in order to gain control. The second main principle was to keep the size of the liquor droplets from the spreaders as constant as possible. That implies testing of different viscosity, pressures and distributions between short and long fibre liquors.

The operators have had similar meetings before and the main problem seemed to have a common understanding. This was exemplified at the meeting with a story about three experts from the boiler vendor quarrelling openly in the control room at Tofte about different explanations. The operators at the meeting agreed that they were too sloppy with writing notes about what problems they experienced and how they tried to solve them. When the process engineer investigates different parameters he has a hard time. When reading the journal, everything seem to be OK, even though they know there had been severe problems during those days. One operator said:

*“I cannot see explanations of why changes have been made when I read the journal.”* Another followed: *“It is important to prove what we do.”*

They all know that changes have to be made to correct disturbances, but they leave the explanations out. At the meeting, they also confessed that they themselves had to improve on this point.

A third operator stated: *“It is in everybody's interest to improve the conditions at the boiler.”*

This was when they discussed how to follow up what they agreed upon at that meeting. This was further emphasised by the department manager when he explained that he needed to know what kind of modifications in the boiler equipment should be taken into account. He told them he needed “proofs” of what to implement.

They all agreed that shared practice across shifts was the first thing that needed to be done. And they stated the necessity of giving feedback and also demanding feedback when changes are made. They also agreed that they ought not to manipulate the process in order to obtain one result that could result in a sub optimal solution.

*“I have nothing against getting a corrective view. We have to be a bit humble in order to follow each other up. We have experienced trouble because some people have tried everything at the same time. It was hard for me to let go of one of my strong theories and accept that I was wrong”* one of the operators stated.

It was decided to do a controlled experiment next week with the long fibre liquor to gain more knowledge. It was also decided to meet 14 days later to evaluate the experiment and decide what to do next. After the meeting, I asked one operator if they would succeed this time: He answered:

*“Yes if we manage to break out of the usual cycle.”*

They managed to perform some experiments and keep desired variables relatively constant. They could then reject some hypotheses as they tested some “extreme” conditions.

However, despite a good dialogue, and some tests, the process engineer in the department could not detect any major improvements in December 1998.

## **A9. Action research**

### **Historical context**

The notion of action research has its origin in the United States where Kurt Lewin (1943) wrote a work encouraging the use of meat entrails in everyday cooking. It had the explicit aim of changing behaviour and recording the outcomes of the attempts to do so. The crucial difference between this work and others was the recognition that the researcher was visible and was expected to have an impact on the experiment (Eden and Huxham, 1996).

*“Soon after the pioneering work in US the Tavistock Institute in UK began a programme of research in the coal mining industry which gradually led to an exposition of the relationship between investigatory research and its implications for action”* (Trist and Bamforth, 1951).

This work was to lead to the development of the socio-technical systems approach to thinking about organisational interventions (Emery and Trist, 1963). This work was strongly aimed at conducting research and undertaking associated theory development alongside with attempts to make significant changes in organisations.

Political matters made further developments difficult in the UK and contact between Emery and Thorsrud in Norway led to the Industrial Development Project, which was a collaboration between LO and NAF<sup>65</sup> and four industrial companies. One outcome of this work is embedded in the Norwegian work legislation act and the industrial development program led to institution building in Norway, IFIM in Trondheim and the Work Research Institute in Oslo<sup>66</sup>.

Since then the concept and content has developed and several contemporary forms of action research have developed (Elden and Chisholm, 1993).

### **Short description of action research (AR)**

Eden and Huxham (1996) use the term action research to

---

<sup>65</sup> LO: Norwegian Confederation of Trade Unions, NAF: Confederation of Norwegian Business and Industry.

<sup>66</sup> Both these institutions have been central in the construction and conduction of the INPRO program, which this case study is a part of.

---

*“...embody research which, broadly, results from an involvement by the researcher with the members of an organisation over a matter which is of genuine concern to them and in which there is an intent by the organisation members to take action based on the intervention.”*

Lewin (1946) and most subsequent researchers have conceived of AR as a cyclical inquiry process that involves diagnosing in a problem situation, planning action steps, and finally implementing and evaluating outcomes. Evaluation leads to diagnosing the new situation anew based on learning from the previous activities cycle (Elden and Chisholm, 1993). A third definition is offered by Rapoport (1970):

*“Action research aims at contributing both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework.”*

Contemporary forms of action research also aim at making change and learning a self-generating and self-maintaining process in the systems in which action researchers work (Elden and Chisholm, 1993).

A distinctive feature of AR is that the research process is carried out in collaboration with those who experience the problem or their representatives. The term AR implies both action and research. Organisational intervention may be full of actions but it does not always meet the demands on rigorous research. *“Nevertheless, the label “action research” is unfortunately often used as an excuse for sloppy research”* (Eden and Huxham, 1996). According to Greenwood and Levin, (1998) for a process to be called AR, it must be systematic and oriented around posing questions whose answers require the gathering and analysis of data and the generation of interpretations directly tested in the field of action.

Another difference between AR and most conventional social science is that, in AR, the research activity is based on a long-term and personal engagement through living with and acting to solve practical problems (p. 94). AR also emphasises democratic values and processes by cocreating knowledge applicable by the researched entities in efforts to increase control over their own situations.

As the research process continues and the research partners gain understanding, the goals of the process are constantly being redefined, refined, and even altered completely. The goal is not an a priori definition of a problem that is then studied by an objective outsider; it is the ongoing collaborative definition of problems relevant to the research partners and the development of information and analyses that enable them to address the defined problems effectively and democratically (p. 94).

AR is a process co-managed by the interested parties, not a technique applied by a professional researcher to other people. A central design challenge in any AR process is structuring arenas for communication that will effectively support an open and inclusive meaning construction process. Cogenerative learning is not merely a methodology or a set of techniques; it is a way of framing an AR process that aims to clarify social positions, communication processes, learning, and action options (p. 114).

The co-generative view is a framework for thinking through how to choose appropriate methods and actions, not a recipe. It is fully and necessarily compatible with the deployment of a wide variety of research techniques and agendas.

In the theory Chapter on learning arenas, I have demonstrated the versatility of the co-generative research model as I have applied it in an industrial context where the stakeholders are production personnel from different communities-of-practice. The model is given in Figure 4.4. Greenwood and Levin (1998) define AR as social research carried out by a team encompassing a professional researcher and members of an organisation or community seeking to improve their situation. AR promotes broad participation in the research process and supports action leading to a more just or satisfying situation for the stakeholders.

AR as a form of research has the following core characteristics:

- AR is context bound and addresses real-life problems.
- AR is inquiry where participants and researchers cogenerate knowledge through collaborative communicative processes in which all participants' contributions are taken seriously.
- AR treats the diversity of experience and capacities within the local group as an opportunity for the enrichment of the research-action process.

- The meanings constructed in the inquiry process lead to social action, or these reflections on action lead to the construction of new meanings.
- The credibility-validity of AR knowledge is measured according to whether actions that arise from it solve problems (workability) and increase participants' control over their own situation.

Action researchers accept no a priori limits on the kinds of social research techniques they use: Surveys, statistical analyses, interviews, focus groups, ethnographies, and life histories are all acceptable, if the reason for deploying them has been agreed on by the AR collaborators and if they are used in a way that does not oppress the participants; Formal quantitative, qualitative, and mixed methods are all appropriate to differing situations. AR is composed of a balance of three elements. If any one of the three elements research, participation and action is missing, then the process is not action research. In an ideal AR process the professional researcher and the stakeholders together define the problems to be examined, cogenerated relevant knowledge about them, learn and execute social research techniques, take actions, and interpret the results of actions based on what they have learned.



## **A10. Implications for the role of process engineer and university teaching**

I have, for each learning arena, discussed implications for a process engineer. In Norway, a process engineer is most likely to have a university degree in chemical engineering and has received it from the Norwegian university of Science and Technology in Trondheim.

A newly educated engineer will need a lot of local knowledge before being able to actively contribute in adding value. A common method for learning is to take part in everyday practice and learn from problems, and through this learn to connect fragments into more and more complex and complete systems. The learning arenas discussed in this thesis are means to structure the process engineer's interactions with process operators, i.e., by taking part in various phases of an operations workshop, the engineer will develop local theories together with operators and at the same time work systematically on longer term aims.

The engineer will be better prepared for this way of working if the universities follow a similar problem oriented way of education. Qvale (1998) argues that engineers ought to learn a different way of managing, -or more generally relating to other people at work,- through working in a different way in university.

Use of Operations workshops enables for a close co-operation between industry and university, as the various phases are conducive as a project task. A student or even a student group could take part in preliminary analyses, the workshop itself, and not least in following up. They would thereby also learn about organisational constraints that may inhibit learning and shared practice. And they could eventually interview operators and then pay useful attention to the important follow up phase and also participate in finding out why tasks from a workshop are not followed up. Another task could be to construct or contribute to the construction of MOPS representations. These could also be coupled with cost factors to make clear a major goal with all optimisation efforts: how much is saved. As plants like Tofte often have scarce resources for following up, students could make a positive contribution, but this should eventually be regarded as a bonus for the plant. INPRO concerns the practical issue of changing the education for engineers so that they are better prepared for working in a participative work organisation (Qvale, 1998b). A good process engineer is in fact an action researcher, he will make changes to understand (experimentation) and help operators to

interpret what has been going on. He has to work together and learn together with the operators in order that both parties should develop. The operators will contribute with their experiences and theories and the engineer may contribute with his experience and theories based on a university degree. As two operators have stated: *“Together we would have been a strong team.”*

As a theoretical part of such a project, the method itself and the cogenerative learning model as a frame for an Operations workshop could be studied as could the way a plant needs to be organised in order to stay competitive.



## REFERENCES

- Argyris, C. & Schön, D.A. (1978). *Organizational Learning: A theory of Action Perspective*. MA, Addison-Wesley.
- Argyris, C. & Schön, D.A. (1996). *Organizational Learning II: Theory, Method, and Practice*. MA, Addison-Wesley.
- Beinum, H. van (1988). *New Technology and Organizational Choice*. QWL Focus. The Ontario Quality of Working Life Centre. Vol 6, Issue 1, pp. 3-11.
- Berger, P. & Luckmann, T. (1966). *The social construction of reality*. Garden City, NY: Doubleday.
- Bergman, P. (1995). *Moderna lagarbeten*. Lund: Arkiv.
- Bertalanffy, L. von (1950). *The theory of open systems in physics and biology*. Science, 111, pp. 23-29.
- Bjørgen, I. A. (1992). *Det amputerte og det fullstendige læringsbegrep*. Norsk Pedagogisk Tidsskrift 1/1992.
- Bohle F. & Rose, H. (1992). *Technik und Erfahrung. Arbeit in hochautomatisierten Systemen*. Frankfurt/New York: Campus Verlag.
- Bohn, R.E. (1994). *Measuring and Managing Technological Knowledge*. Sloan Management Review / Fall 1994.
- Booth, P. (1989). *An Introduction to Human-Computer Interaction*. Lawrence Erlbaum Ass. Publishers.
- Brehmer, A. (1993). *Operatörsstöd för styrning, diagnostik och processutveckling vid papperstilverkning. Resultat och slutsatser från intervjuer med maskinförare vid Obbola Liner, Obbola*. Uppsala: CMD.
- Brehmer, B. (1987). *Development of Mental Models for Decision in Technological Systems*. In J. Rasmussen, K. Duncan & J. Leplat (eds.) *New Technology and Human Error*. Chichester: John Wiley & Sons.
- Brown, J.S., and P. Duguid. (1991). *Organizational Learning and Communities-of-Practice. Toward a unified view of Working, Learning, and Innovation*. Organizational Science, Vol. 2, No. 1, pp. 40-57.
- Buchanan, D.A. & Bessant, J. (1985). *Failure, Uncertainty and Control: The Role of Operators in a Computer Integrated Production System*. Journal of Management Studies, 22, 3, pp. 292-308.

Cannon-Bowers, J.A., E. Salas, and S. Converse. (1993). *Shared Mental Models in Expert Team Decision Making*. In Individual and Group Decision Making, ed. N.J. Castella, Jr., pp. 221-246. Hillsdale, NJ: Lawrence Erlbaum Associates.

Davidson, B. & Svedin, P. O. (1995). *Det stora pappersbruket. Om förutsetningar för lärande i modernt industrarbete*. Manuskript. Linköping: Institutionen för pedagogik och psykologi.

Dreyfus, S.E. & Dreyfus, H.L. (1986). *Mind over Machine*. Oxford: Basil Blackwell.

Eden, C and Huxham, C (1996). *Action Research for the Study of Organizations*. In Clegg, Stewart R., Cynthia Hardy and Walter R. Nord: "The Handbook of Organization Studies", Sage, London

Eijnatten, F.M. von (1993). *The Paradigm that Changed the Work Place*. van Gorcum, Assen.

Elden, M & Chisholm (1993). *Towards the integration of the social sciences*. Human relations, vol. 46, no 2, special action research issue

Elden, M & Levin, M (1991). *Co-generative Learning: Bringing Participation into Action Research*. In Participative Action Research, Whyte, W. (ed.), Newbury Park, CA: Sage Publications.

Ellström, P.E. (1996). *Operatörskompetens – vad den är och hur den kan utvecklas*. DUP-resultat, NUTEK, Stockholm. (In Swedish).

Emery, F.E. and M. Emery (1974) *Participative design*. Centre for Continuing Education, ANU, Canberra.

Emery, F.E. & Thorsrud, E. (1970). *Mot en ny bedriftsorganisasjon*. Tanum, Oslo. (In Norwegian).

Emery, F.E. & Thorsrud, E. (1976). *Democracy at work*. Leiden: Martinus Nijhoff.

Emery, F.E. & Trist, E. (1963). *The causal texture of organizational environments*. Human Relations. 18: 21-32.

Engelstad, P.H. (1970a). *Sociotechnical approach to problems of process control*. In F. Bolam (Ed.) Papermaking problems and their control. British Paper and Board Makers Association.

Engelstad, P.H. (1970b). *Teknologi og sosial forandring på arbeidsplassen*. Tanum, Oslo

Foss, B.A., R. Klev, M. Levin and K.M. Lien (1995). *Integrated production systems for the process industries*. In: Proc. of The First World Congress on Integrated Design and Process Technology. pp. 276-282. Austin, TX, USA.

Greenwood, D.J. and Levin, M. (1998). *Introduction to Action Research*. Thousand Oaks: CA. Sage publications.

- Gullers, P. (1988). *Automation –Skill-Apprenticeship*. In Goranzon, B. and Josefson, I (Eds.) Knowledge, Skill and Artificial Intelligence. Berlin: Springer Verlag, 1988.
- Guba, E.G. & Lincoln, Y. S. (1985). *Naturalistic Inquiry*. Thousand Oaks, CA: Sage Publications
- Göranzon, B. and Josefson, I. (Eds.) (1988). *Knowledge, Skill and Artificial Intelligence*. Berlin: Springer Verlag
- Hendry, C. (1996). *Understanding and creating whole organizational change through learning theory*. Human Relations, Vol. 49, No. 5, pp.621-641.
- Herbst, P.G. (1976). *Alternatives to hierarchies*. Leiden: Martinus Nijhoff.
- Hirschorn, L (1984). *Beyond Mechanization*. Cambridge, Massachusetts, MIT Press.
- Husemoen, M.S. (1997). Bridging operation and design. PhD thesis. Department of Industrial Economics and Technology Management, Norwegian University of Science and Technology. Trondheim, Norway.
- Jakobsen, H. (1994). Styring av et cellulose kokeri. Siv.ing dissertation. Department of Organisation and Work Life Science, Norwegian Institute of Technology. Trondheim, Norway. (In Norwegian).
- Johnson-Laird, P.N. (1983). *Mental models*. Cambridge University Press, Cambridge.
- Kim, D. (1993). *The Link between Individual and Organizational Learning*. Sloan Management Review, vol. 35, no. 1, pp. 37-50.
- Kolb, D.A. (1984). *Experiential Learning*. Prentice-Hall, Englewood Cliffs, NJ.
- Lave, J. & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*. Cambridge: Cambridge University Press.
- Levin, M. et al. (1994). *Ledelse og teknologi*. Universitetsforlaget, Oslo (In Norwegian).
- Levin, M. (1993). *Technology transfer as a learning and development process: an analysis of Norwegian programmes on technology transfer*. Technovation, Vol. 13 (8) pp. 497-518.
- Levin, M (1995). *Technology Transfer is Organizational Development - An investigation in the relationship between technology transfer and organizational change*. International Journal of Technology Management.
- Lewin, K. (1943). *Forces behind food habits and methods of change*. Bulletin of the National Research Council, 108, 35-65.
- Lewin, K. (1946). *Research on minority problems*. The Technology Review, 48 (3).
- Lundquist, K. (1996). *Nya organisationsformer inom Processindustrin*. DUP-resultat, NUTEK, Stockholm. (In Swedish).

- Mayo, E. (1933). *The human problems of an industrial civilization*. New York: Macmillan.
- Morgan, G. (1986). *Images of organizations*. Beverly Hills, CA, Sage Publications.
- Nonaka, I., and H. Takeuchi. (1995). *The Knowledge Creating Company. How Japanese Companies Create the Dynamics of Innovation*. Oxford: Oxford University Press.
- Nordhaug, O. et al. (1990). *Læring i organisasjoner: Utvikling av menneskelige ressurser*. Oslo, Tano.
- NOU nr. 4 (1991): *Veien videre til studie – og yrkeskompetanse for alle*, Oslo, Statens forvaltningstjeneste.
- Olsson, G. (1996). *Operatörarbete i utveckling. Uppgift, verktyg, kunskap*. DUP-resultat, NUTEK, Stockholm (In Swedish).
- Pasmore, William E. (1988). *Designing Effective Organisations, The Sociotechnical Systems Perspective*. Wiley. John Wiley & Sons.
- Patton, M. Q. (1990). *Qualitative Evaluation and Research Methods*. 2nd ed. Newbury Park, CA: Sage Publications.
- Perby, M.L. (1995). *Konsten att bemästra en process. Om att förvalta yrkeskunskande*. (The art of mastering a process). Smedjebacken: Gidlunds Forlag. (In Swedish).
- Porter, M. E. (1985). *Competitive Advantage: Creating and Sustaining Superior Performance*. The Free Press, New York.
- Qvale, T.U. (1998). *Past, Present and Future of Quality of Work Life in Norway: Some reflections after 30 years of national reforms and research programs*. Invited paper to the Organizational Psychology Division 24<sup>th</sup> International Congress of Applied Psychology. San Francisco August 9-14, 1998.
- Qvale, T.U. (1998b). *The INPRO Programme: A Three Level Action Research Strategy for Changing the Education of Engineers and the Relationship between University and Industry*. Paper to the Fred Emery Memorial Conference: On the future of universities and education. 10-13. April 1998, Sabanci Universiteti, Istanbul.
- Rapoport, R.N. (1970) *Three dilemmas in action research: with special reference to the Tavistock experience*. Human Relations, 23 (6), 499-513.
- Schein, E.H. (1993). *On dialogue, culture and organizational learning*. Organizational dynamics, vol. 22, no 2, pp. 40-51.
- Schön, D. A. (1983): *The Reflective Practitioner: How Professionals Think in Action*. Reprinted 1995 by Arena Books, London.
- Senge, P.M. (1990). *The Fifth Discipline – The art and practice of the learning organization*. Currency Doubleday, New York.

Simensen, J. (1998). *Learning support in process plant operation*. PhD dissertation, Dept. of Engineering Cybernetics. Norwegian University of Science and Technology, Trondheim, Norway.

Skule, S. (1994). *From Skills To Organizational Practice. A study of the relation between vocational education and organizational learning in the food-processing industry*. PhD dissertation, Dept. of Industrial Management and Work Science, Trondheim, Norway.

Taylor, F W.: (1911). *The Principles of Scientific Management*. Newton Library Harper & Row.

Toffler, A. (1990). *Powershift: Knowledge, Wealth and Violence at the Edge of the 21th Century*. New York: Bantam Books.

Trist, E. (1981). *The Evolution of Socio-technical Systems as a Conceptual Framework and an Action Research Program*. In Perspectives on Organization Design and Behaviour, Van de Ven, A.H. & Joyce, W.F. (eds.), New York, John Wiley & sons.

Trist, E. & Bamforth, K. (1951). *Some Social and Psychological Consequences of the Longwall method of Coal-getting*. Human Relations, vol. 4, No.1 pp. 3-38.

Ullmark, P. (1996). *Förändringsarbete – erfarenheter från att utveckla system och organisation*. DUP-resultat, NUTEK, Stockholm. (In Swedish).

van Hauen et.al (1995). *Den lærende organisasjon – om evnen til å skape kollektiv forandring*. Industriens forlag. ISBN 87-600-0054-6.

Weber, M. (1947). *The theory of social and economic organization*. New York: Oxford University Press.

Woodward, J. (1965) *Industrial Organisation: theory and practice*. London: Oxford University Press.

Zuboff, S. (1988). *In the Age of the Smart Machine - The Future of Work and Power*. Basic Books, Inc., Publishers.

Øyum, L (1993). *Historien om B91*. Siv.ing dissertation. Department of Organisation and Work Life Science, Norwegian Institute of Technology. Trondheim, Norway. (In Norwegian).

### **Internal reports (IR) and documents from Södra Cell Tofte**

Borgersen, R. (operators' trade union leader) (1996) *Speech held at Leangkollen*.

Gravdal, M. (1993) *Beskrivelse rundt utviklingsoppgave ved Norske Skog Tofte for Dr.ing. kandidat innen området: Nye organsasjonsformer*.

Gravdal, M. (1994) *ORIENTERING / STATUS / FREMDRIFT - LOOK 92*.



Medarbeiderskap (1996). *Employeeeship course book.*

Stendal, L. (1997) *Evaluering av Medarbeiderskap på Norske Skog Tofte 1997. (Evaluation of The Employeeeship Project at Norske Skog Tofte 1997).*

Storebråten, S. (1990). *Sulfatfabrikken – virkesforsyningens søppel plass (The sulphate pulp mill – the dumping ground of wood supply).* Foredrag i PTF, Masseteknisk gruppe, 9. oktober 1990, Oslo.

Thun, I. (1995). *Summary of the “Vettre conference.”*