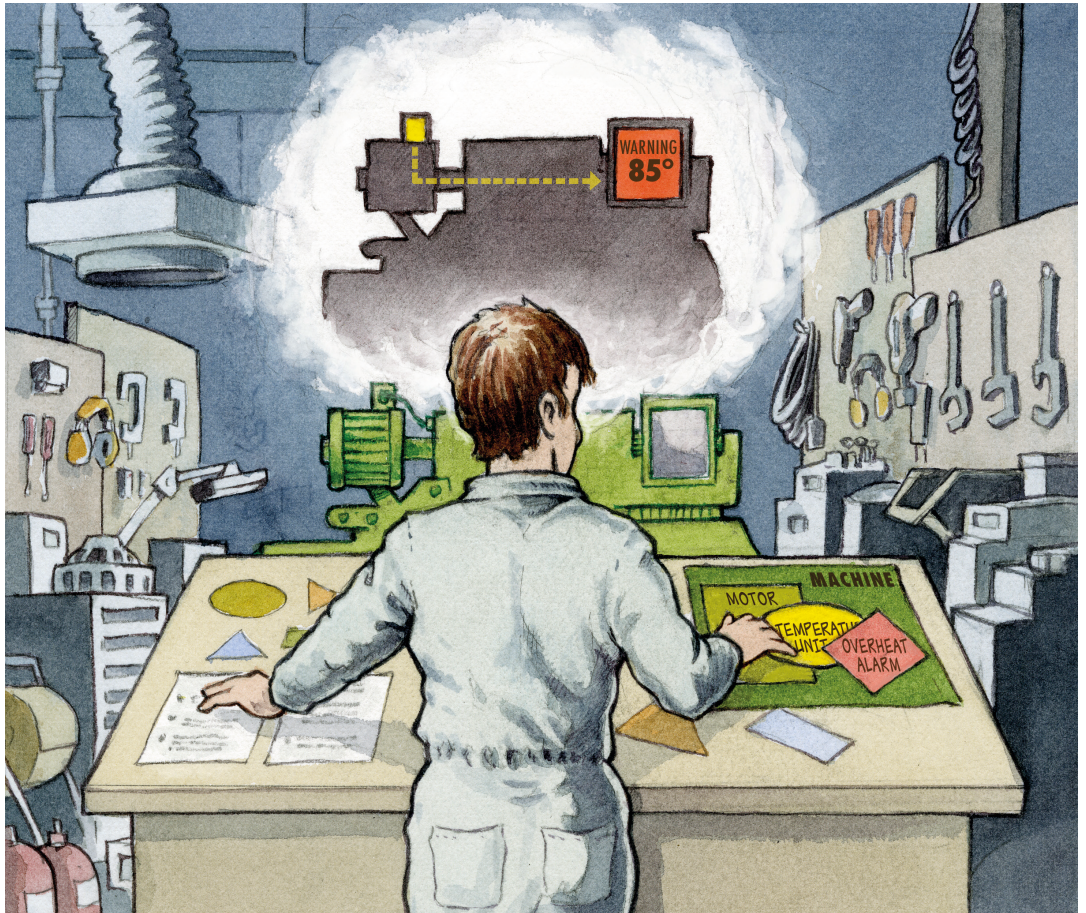# Shaping thought through action
A study of the use and design of technical information

Jonatan Lundin

MÄLARDALEN UNIVERSITY
SWEDEN

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SHAPING THOUGHT THROUGH ACTION

A STUDY OF THE USE AND DESIGN OF TECHNICAL INFORMATION

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MÄLARDALEN UNIVERSITY
SWEDEN

Akademin för innovation, design och teknik

Abstract

This dissertation deals with the design of technical information, such as a user manual for an industrial device, based on the searching and reading behaviour of process operators and maintenance technicians. Such industrial professionals, who use tools like measuring equipment, are sometimes unable to get the support they need from searching and reading in a text- and image-based tool manual in order to perform work tasks. If such a manual is the only available source of information, the user will either give up or attempt a workaround which ends up compromising the safety, quality, satisfaction, efficiency or effectiveness of the work task. Research within technical communication and human-computer interaction suggests how manuals can be designed to support users in accomplishing tasks. These suggestions are based upon studies of how users approach the use of tools and tool manuals, as well as how the design of procedural and declarative information supports users. However, there is limited knowledge about how users search and read manuals, and how manuals can be designed to support such searching and reading behaviour. This dissertation aims to contribute knowledge to technical communicators about how technical information can be designed to support industrial professionals in accomplishing their work tasks. An ethnographic research method was selected to study the behaviour exhibited by process operators and maintenance technicians' while they search and read sources of information in order to perform work tasks with tools. The results show that some participants were unable to perform a task after searching and reading the manual. The empirical material has been analysed using Vygotsky's sociocultural theory. This was to gain a deeper understanding of how thought and language influence—and are influenced by—searching and reading behaviours, as well as the task behaviours during tool use. This dissertation's contribution is a design method for technical communicators that will enable them to support users in the shaping of mental representations about what results are possible to accomplish with a tool. The method involves the design of tangible tokens that signify the results and components of a tool. As the end-user arranges these symbols into a result model they are supported in their process of shaping a mental representation.

SAMMANFATTNING

Avhandlingen handlar om hur operatörer och underhållstekniker i industrin söker och läser i information för att utföra arbetsuppgifter, samt hur teknikinformation kan designas utifrån deras sök- och läsbeteenden. Yrkesverksamma i industrin, som använder verktyg i form av exempelvis mätutrustning, upplever ibland att de inte får stöd i att utföra sina arbetsuppgifter genom att söka och läsa i en text- och bildbaserad verktygsmanual. Om en sådan manual är den enda tillgängliga informationskällan kommer de antingen att ge upp eller försöka med en tillfällig lösning vilket äventyrar säkerheten, kvaliteten, tillfredsställelsen, eller effektiviteten för arbetsuppgiften. Forskning inom teknikinformation och människa-datorinteraktion föreslår hur manualer kan designas för att stötta användare i att utföra arbetsuppgifter. Dessa förslag baseras på studier om hur användare går tillväga när de använder ett verktyg och dess manual, samt hur utformningen av instruktioner och beskrivningar stöttar användare. Dock finns begränsad kunskap om hur en användare söker och läser i manualer och hur de kan designas utifrån användarens sök- och läsbeteende. Syftet med avhandlingen är att bidra med kunskap till teknikinformatörer om hur teknikinformation kan designas för att stötta yrkesverksamma i industrin i att utföra sina arbetsuppgifter. En etnografisk metod valdes för att studera hur operatörer och underhållstekniker söker och läser i informationskällor när de utför arbetsuppgifter med olika verktyg. Resultaten visar bland annat att vissa deltagare inte kunde utföra en arbetsuppgift efter att ha sökt och läst i manualen. De observerade beteendena analyseras utifrån Vygotskys sociokulturella teori. Detta för få fördjupad kunskap om hur tanke och språk påverkar—och påverkas av—sök- och läsbeteenden samt hur verktyget användes. Avhandlingens bidrag är en designmetod som vänder sig till teknikinformatörer för hur de kan stötta användare i att forma en mental representation om vilka resultat som går att uppnå med ett verktyg. Metoden innebär att teknikinformatören designar symboler som representerar resultat och komponenter i ett verktyg. När användarna arrangerar dessa symboler till en resultatmodell, stöttas de i att forma en mental representation om de resultat som går att uppnå med verktyget.

ACKNOWLEDGEMENTS

First, I would like to sincerely thank my dedicated supervisor Professor Yvonne Eriksson for providing invaluable feedback and guidance throughout the research process. I would also like to express my sincere gratitude to my co-supervisor Senior Lecturer Carina Söderlund. Without their supervision, I would not have been able to progress toward my academic goals. I'd also like to express thanks to my co-supervisor Associate Professor Inger Orre for her competent and well-informed guidance.

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Finally, I would like to sincerely thank my family who, in memory of my sister, has endured my research journey. I hope my children Hanna and Filip will someday understand what kept their father busy.

PREFACE

Throughout my working life in the technical communication business, there is one thing that has always bothered me. I have struggled to understand how one might design technical information in order to improve its usefulness. The kind of technical information I have been dealing with over the past 25 years is manuals designed in parallel with product development. Such technical information targets professionals working with industrial equipment and consists of text and images organised in a certain structure on different topics, such as how to operate a device or piece of software. My desire to understand how technical information can be better designed first arose upon hearing reports that the users of the manuals my colleagues and I had designed were having difficulties using them, and therefore seemed to not prefer them. I have been actively looking for answers ever since. Not knowing the answers led to growing dissatisfaction in my work as a technical communicator—an experience I believe many technical communicators share. This is because manufacturing companies are expected to deliver usable technical information. The pressure to design usable technical information is likely to continue rising as the number of advanced tools and information professionals are using and searching seem to increase. Manufacturing companies hire technical communicators to deliver. If you feel you cannot deliver, you either live with it or do something about it.

Some years ago, I decided to do something about it. This dissertation contributes knowledge to the field of technical communication, and it relieves some aspects of the challenge that has been bothering me for so long. If you're a fellow technical communicator reading this, hopefully it can bring some relief to you too.

Västerås, November 2019

Jonatan Lundin

LIST OF PAPERS

This dissertation is based on the following peer-reviewed papers. When a paper is referenced in the text, a corresponding capital letter is used as indicated below.

A. vanLoggem, B. & Lundin, J. (2013). Interaction with user documentation: A preliminary study. In: *Proceedings of International Conference on Information Systems and Design of Communication (ISDOC2013)*, Lisboa, Portugal, July 2013, pp. 41-46.

B. Lundin, J. (2014). Towards a normative conceptual framework for information-seeking studies in technical communication. In: *Proceedings of International Conference on Information Systems and Design of Communication (ISDOC2014)*, Lisboa, Portugal, May 2014, pp. 15–19.

C. Lundin, J., Söderlund, C. & Eriksson, Y. (2016). Design challenges for technical communicators. In: *Proceedings of the 34th ACM International Conference on the Design of Communication (SIGDOC '16)*, Silver Spring, USA, September 2016, article no. 20.

D. Söderlund, C. & Lundin, J. (2016). What is an information source? Information design based on information source selection behavior. *Communication Design Quarterly Review*, 4(3), pp. 12-19.

E. Lundin, J. & Eriksson, Y. (2018). An investigation of maintenance technicians' information-seeking behavior in a repair center. *IEEE Transactions on Professional Communication*, 61(3), pp. 257-274.

F. Lundin, J. (2019). Designing technical information from a sociocultural theoretical perspective. In: Eriksson, Y. & Paetzold, K. (Eds.) *Proceedings of the 2nd SIG conference on human behaviour in design (HBiD 2019),* Tutzing, Germany, April 2019, pp. 75-87.

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ADDITIONAL PUBLICATIONS

G. Lundin, J. (2015). *Designing technical information: Challenges regarding service engineers' information-seeking behaviour.* Licentiate thesis. Västerås: Mälardalen University.

H. Lundin, J. (2015). How do you design for findability? *Communicator*, Summer 2015, pp. 14-17.

I. Lundin, J. (2017). Why do users often not understand manuals? In: European Association for Technical Communication – tekom Europe e.V. (Ed.) *Year Book 2017*, volume 1, pp. 31-44.

CONTENTS

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1 | INTRODUCTION

Professionals, such as process operators and maintenance technicians in industrial workplaces, commonly find themselves as users who do not know how to use the tools, such as a software, required to accomplish a given work task. In my experience working 25 years as a technical communicator, such users are often unable to get the support they need by searching and reading in the technical information designed for end-users by the manufacturer of the tool. This is in line with previous technical communication research which has reported that users find such technical information, consisting of text and images, difficult to use. Users say they cannot find what they need or understand what they find (Martin, Ivory, Megraw & Slabosky 2005; Novic & Ward 2006a; Novic & Ward 2006b; Wieringa, Moore & Barnes 1998). Previous research has also reported that the technical information supplied by the manufacturer is less preferred by many users as a source for solving a problem (Ceaparu, Lazar, Bessiere, Robinson & Shneiderman 2004; Costa, Aparicio & Pierce 2009; Mehlenbacher, Wogalter & Laughery 2002; Mendoza & Novick 2005; Novick, Elizalde & Bean 2007; Welty 2011).

At best, users may find other sources of information, not designed by the manufacturer, that are helpful when an information need arises. There is a risk that such alternative sources provide information that is not in accordance with information published by the manufacturer. Acting on incorrect information can lead to negative consequences—especially in industrial safety-critical settings—such as damage, injuries or warranties being voided.

In certain industrial settings where, for example, internet usage is not allowed, a manufacturer's technical information may be the only accessible source of information. If a user neglects it, or is not getting anywhere by using it, they are left without support. As a consequence, they create a workaround, give up, or have to accept a poor result, which ends up compromising the safety, quality, satisfaction,

efficiency and effectiveness of their work task. Ultimately, the manufacturer's investment in employing technical communicators to design technical information is not returned.

Research within the field of technical communication and human-computer interaction sends a clear message. Technical communicators need to understand how users actually behave when using a tool and technical information. That way, they can continue to improve the usability of technical information. Previous research by Carroll (1990) for example, has shown that novice users trying to learn a new software learn by doing, and by thinking and reasoning. When learning, users look for a meaningful context and meaningful tasks to work on, and relate new experiences to earlier experiences and prior knowledge. Furthermore, they learn from their mistakes. Many users seem primarily uninterested in reading about the tool itself but, instead, are interested in learning how to use it to gain a result. Such insight has led the field to move from an expository information design approach, which supports reading-to-learn, to an instructional design approach which supports reading-to-do (van der Meij, Karreman & Steehouder 2009). This means that technical information becomes an aid that supports problem-solving in a work task.

Nevertheless, consensus has been reached among technical communication and human-computer interaction researchers: When using a tool, users shape a mental model about it upon which they act. Scholars in these fields discuss how to best support the user in their process of shaping a mental model about a tool. Some scholars have investigated how procedural and declarative information can offer support. Others have suggested that information design can support the user in shaping a mental model by encouraging exploration of the tool.

Previous research also highlights that reading an instruction about performing a task in a tool, such as a piece of software, is an iterative interaction between the readers' cognitive system, the instruction and the tool (Ganier 2012). This interaction takes place throughout the phases of searching, understanding and applying information in an instruction, and it puts a heavy load on the cognitive system (Ganier 2004).

Despite this, more knowledge is needed on how technical information can be designed to increase a user's chances of accomplishing a work task using tools. Previous research acknowledges that users search and read technical information. But very little research can be found on how users search and read, and how to design technical information that supports their searching and reading behaviours.

This is in line with Andersen et. al. (2013) who states that knowledge on user behaviour is lacking in the technical communication community.

AIM AND RESEARCH QUESTIONS

The aim of this dissertation is to contribute knowledge to technical communicators about how technical information can be designed to support industrial professionals in accomplishing their work tasks. The objective is to suggest a design method on how technical information can be designed to increase process operators and maintenance technicians' chances of accomplishing a work task using tools in industrial settings.

The research questions are:

1. How do process operators and maintenance technicians search and read information to use tools when performing a work task?

2. What are the implications for the design of technical information by technical communicators, to increase process operators and maintenance technicians' chances of accomplishing a work task using tools?

DELIMITATIONS

Research conducted for this dissertation is delimited to individuals who monitor and control industrial production processes and perform maintenance on industrial machines. The focus is on work tasks that rely on the frequent use of advanced technical tools, such as, a software to control a production process. From the point of view of a technical communicator designing technical information for such tools, these individuals are the end-users since they are the ones operating the tool. Other types of user groups, which might be included throughout the lifecycle of a tool, were not within the scope of this dissertation.

From time to time, new tools are introduced to a workplace or individuals enter a new workplace and must learn its tools. In such cases, there are many different ways an individual can obtain the relevant knowledge they need. Research is delimited to workplaces and tasks where they were not under heavy stress but could

spend some time independently seeking information. This was to learn and develop knowledge about tools within the time frame that a work task needed to be accomplished. Research is further delimited to individuals who had some freedom to decide what work tasks to perform and how, what tools to use, and who were motivated to perform work tasks. The focus is on work tasks involving no or little risk of economic damage or human injury if a tool was used incorrectly.

CONTRIBUTIONS

This dissertation seeks to contribute to a more comprehensive understanding of process operators' and maintenance technicians' behaviour while searching and reading technical information about tools in order to accomplish work tasks. It does so by illuminating what these behaviours might indicate from the psychological perspective of how thought and language influence —and are influenced by —searching and reading behaviours, as well as the task behaviours in a tool.

This dissertation also seeks to fill the knowledge gap in the information design field, and especially the technical communication field, when it comes to understanding how technical information can be designed. This is to increase process operators and maintenance technicians' chances of accomplishing a work task using tools. It does so by drawing upon Vygotsky's sociocultural theory to suggest that the technical communicator is the knowledgeable other who scaffold the user to build a result model using psychological tools. The psychological tools are the mediating agent, and the action of using them helps to mediate or shape thought. Thereby, users can be supported in shaping a mental model of the results that can be accomplished with a tool, which then enables them to shape goals and task plans that can be accomplished.

Additionally, the analysis and discussion of this dissertation contribute new knowledge on how Vygotsky's sociocultural theory can be used to inform the design of technical information.

RELATED RESEARCH

This section studies the current understanding of user behaviour related to how users use tools and technical information. Current research is presented on the topic of how technical information can be designed in order to best support users. The bulk of the research comes from the fields of technical communication, human-computer interaction and psycholinguistic research.

Behaviour of users when using, searching and reading

According to Sticht, Robert, Lynn and Diana (1977), Sticht (1985), Diehl and Mikulecky (1981), Mills, Diehl, Birkmire and Mou 1995, and Redish (1989), technical information can be used to read-to-learn, read-to-do and read-to-learn-to-do. Reading-to-learn is a situation where the users' primary goal is to absorb and retain information for future recall (Sticht 1985). Reading-to-learn is not directly related to the need to perform a task in a tool but rather, for example, to making a purchase decision. Users who read-to-do are performing a work task at their job and using technical information to be able to accomplish the work task (Diehl & Mikulecky 1981). The hybrid, coined as read-to-learn-to-do following on Redish (1989), is equivalent to a situation where the users are not using the tool at their job in a real work task. Instead, they are in a training situation outside of work and using a manual, such as a computer tutorial, to learn about the tool in order to know what to do later when using it to execute work tasks.

The technical communication field seems to agree that most users turning to technical information do so in order to read-to-do or read-to-learn-to-do and thus, the research on information design has moved from the design of expository texts to instructional design (van der Meij, Karreman & Steehouder 2009). However, Albers (2012) notes that technical communicators often focus on supporting users to efficiently complete a task by reading-to-do in highly structured situations. In some cases, communication situations are complex, but not highly structured, since they require a mix of information-seeking, problem-solving, and decision making as users read information and make decisions. Albers (2012) makes the case that many communication situations have shifted to complex situations and thereby technical communicators ought to focus on designing technical information that supports reading-to-decide.

We know that users employ different strategies in reading-to-do and reading-to-learn-to-do situations. Following a survey, Schriver (1997) identified three different strategies:[1]

(1) 23% of the participants said they would read the manual before performing any task with a tool. Only after having reading the instructions would they start using a tool.

(2) 41% of the participants said they would start using a tool and read-to-do concurrently, by alternating between the manual and the tool.

(3) 17% of the participants said they would start using a tool based on what they know and read-to-do only in case of doubt, when they experienced difficulty using the tool.

Ganier (2004) suggests there are two main strategies. Either the user reads the instructions, prior to using the tool. Or, they start to use the tool and consult the manual only in cases of doubt.

Research on user behaviour has revealed that novice users in a reading-to-learn-to-do situation, trying to learn a software word processor that is new for them, employ strategy number three in Schriver's (1997) taxonomy. According to Carroll and Rosson (1986), who draw upon Piaget's theory of cognitive development, such users are active, interested in throughput and start to use the tool based on what they know rather than start by reading. They actively develop knowledge about tool usage from independent discovery, where existing knowledge is used to explore and make sense of the tool.

According to Carroll and Rosson (1986), novice users are rather impatient and are not willing to invest time in reading to learn how to use a tool prior to using it. This is a paradox of the active user since, if the individual indeed would have invested in learning by reading prior to using the tool (according to strategy number one in Schriver's 1997 taxonomy), many of the difficulties that later would come could likely be avoided. Instead, the users jumped into the unknown, and only if they erred would they then turn to the manual. And users do commit errors. Users spend 25 to 50 % of their time on correcting errors (van der Meij & Carroll 1998). Users' mistakes can be categorised as semantic errors, syntactic errors and slips (van der Meij & Carroll 1998).

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[1] 19% of the participants said they would not use the manual at all.

Ganier (2004) highlights that it is mainly experienced users who start to perform a task with a tool and consult the manual only in cases of doubt, which contradicts Carroll's findings. Nevertheless, a review on the use and design of instructions, principles and examples by Eiriksdottir and Catrambone (2011) highlights that users seldom read manuals from beginning to end before attempting to use a tool. However, it is likely that whether users consult the manual before using a tool or only when in doubt depends on many factors. Such factors might include the type of tool and its complexity, how knowledgeable the user is about the task domain and the tool and the calculated risk of causing damage to equipment or people.

Previous research suggests that finding specific information involves a number of stages. The research field of library and information science is concerned with understanding why individuals set out to seek information and how they seek. This field has studied behaviours related to information-seeking within various demographic groups and contexts for more than six decades (Case 2007). Wilson (1999) suggests that library and information science research is divided into three areas of study: information-search behaviour, which is a subset of the information-seeking behaviour field which, in turn, is a subset of the information behaviour field. The study of previous research in this field focuses on information-seeking behaviour and information-search behaviour.

Belkin, Brooks and Oddy (1982) suggest that information-seeking is a conscious act of obtaining information in order to resolve a problem. An individual needs information since their current knowledge is not adequate enough to solve the problem at hand. The information need triggers an information-seeking task in which the individual seeks out relevant and preferred information sources. Information-seeking, according to Wilson (1981), is a human task performed by individuals to satisfy an underlying cognitive information need. According to Wilson (1981), an information-search involves the interactions between a user and an information system, where computer-based information retrieval systems may be considered as one type. Work tasks are contexts in which individuals engage in information-seeking tasks (Byström & Järvelin 1995; Byström 2002; Li & Belkin 2010; Vakkari 2003).

However, very little research could be found related to process operators and maintenance technicians' information-seeking behaviour while consulting technical information to learn how to use a tool for the purpose of accomplishing a work task. Furthermore, the library and information science research field focuses

on behaviours related to information-seeking within sources that have a query interface, such as humans or databases, and not on information-seeking in sources such as user manual textbooks.

Guthrie and his colleagues (Dreher & Guthrie 1990; Guthrie & Mosenthal 1987; Guthrie 1988; Guthrie, Britten & Barker 1991) have developed a model on the searching and reading process in textbooks that lack a query interface, but instead have a table of contents and index. Their model involves five stages: (1) setting the goal, (2) selecting a category within the document to examine, (3) skim-reading to extract relevant information from a category, (4) reading to comprehend to integrate the extracted information to previous obtained information and (5) recycling steps one to four until the goal is reached. Their model is for the most part based on studies of students seeking the answer to a question posed to them in a classroom setting at school. Wright (1999), depicts three stages individuals go through while using printed instructions in order to understand how to use a tool: searching, comprehending and applying information.

The models of Wright (1999) and Guthrie and his colleagues (Dreher & Guthrie 1990; Guthrie & Mosenthal 1987; Guthrie 1988; Guthrie, Britten & Barker 1991) do not explicitly take individuals' information needs into account. van Loggem (2017) does involve individuals' information needs in the process and divides documentation interactions into four stages: needing information, seeking information, filtering information and applying information. The van Loggem (2017) model draws upon library and information science scholars such as Blandford and Attfield (2010), and not upon the models of Wright or Guthrie and his colleagues. Neither has the van Loggem (2017) model been empirically validated in the context of interacting with documentation.

We know that reading a found procedural text in order to guide performance involves a number of stages. Guthrie, Bennett and Weber (1991) propose that the process of transforming procedural information into action involves four stages: (a) forming a conceptual model; (b) encoding the procedures; (c) self-testing; and (d) self-correction. Forming a conceptual model involves shaping a mental representation of both the outcome of the procedure and the steps in the procedure. The second stage, encoding the procedures, involves identifying and encoding separate, executable steps from the procedural information. Self-testing involves evaluating the outcome of the procedure against a standard, and self-correction involves repairing a mistake identified through self-testing. Bovair and Kieras (1991)

suggest that procedure acquisition involves three main stages: (a) reading compre-hension, (b) procedure comprehension and (c) executing the procedure. Their model assumes a distinction between declarative and procedural knowledge. In their model, the reader first constructs a declarative representation from compre-hending the procedure text. Once a declarative representation has been con-structed, the reader then constructs a procedural representation, which supports the execution of the procedure. Ganier (2004) states that reading instructions to carry out a task is a complex cognitive activity which involves: (a) the instructions, (b) the tool the user is using, (c) the user's prior knowledge of the tool, and (d) cognitive characteristics (such as ability or working memory capacity). A model by Ganier (2004) depicts five cognitive stages that are involved while instructions are being processed: (a) setting and holding a goal representation, (b) integrating in-formation from the document, the tool and the user's prior knowledge, (c) action planning and executing the action plan, (d) activity regulation and monitoring, and (e) integration in long-term memory. These stages show that reading instructions and executing a procedure is a complex process that takes place between the user's cognitive processes, the instruction and the things in the world the user is inter-acting with. Once the user has shaped a mental model of what they have read, they must shape an action plan which is executed. The models of Guthrie, Bennett, and Weber (1991) and Ganier (2004), but not the model of Bovair and Kieras (1991), include an evaluation stage where it is determined whether the outcome of an ac-tion matches the action plan. Only Ganier's (2004) model relates to situations where a user is using a manual to understand how to use a tool, such as a piece of software.

We also know that users often alternate between reading a step in an instruction and executing the step, rather than first reading the entire instruction first before proceeding to execute the task using the tool. One reason why users do not read the entire instruction at once and then execute the steps, is due to the cognitive effort required (Guthrie, Bennett & Weber 1991). Alternating between reading one or a few steps and executing them requires little cognitive effort, and is therefore an attractive method (Duggan and Payne 2001).

Research in this area is not always clear if the instruction concept is a collection (often called a user manual) of different step-by-step sequences, each for a differ-ent work task users can perform in the tool at different times. Or if it's a single step-by-step procedural text covering a single task. Nevertheless, limited knowledge could be found on how users use a tool after having searched and read,

how many cycles of searching and reading users perform to complete an overall work task or how users search and read within each of these cycles.

Reasons why manuals can be difficult to use

One reason why manuals can be difficult to use relates to how the information is designed. Wright (1981) suggest that the hindrance of not understanding instructions falls into three categories: (1) information is wrong, (2) language and instructions may be hard to understand, (3) information may not be properly organised for the task. Another difficulty lies in the relationship between the text and the tool. If the user cannot identify the physical object which the procedural text is referring to, such as a knob in the user interface, they will not be able to execute the task (Bovair & Kieras 1991).

Information that is designed to be read linearly may cause difficulties for users who tend to start tasks and consult the manual only when in doubt.[2] This is because users in such a situation are probably not interested in reading the entire manual, but only selected parts which are relevant to their uncertainty. This means that, as Ganier (2004) points out, a user manual for expert individuals should be modularised as a collection of instructions so that individuals can access the needed segment of information and understand it without having to read the whole manual linearly. This is in line with Baker (2013), who suggests the technical communicator designs topics, he calls every page is page one topics. He suggests a number of principles for the design of such standalone topics, namely that they are self-contained, have a specific and limited purpose, conform to a type, establish their context, assume the reader is qualified, stay on one level and link richly. However, these principles are based on Baker's extensive experience as a practitioner in the field of technical communication, not on empirical research. Nevertheless, the work of Baker and others shows that there is an ongoing discussion among practitioners about how to design useful technical information.

Another reason why instructions may be difficult to use, and why users avoid them is illuminated by Eiriksdottir and Catrambone (2011), and Ganier (2004, 2012). They state that users shape a mental model when both reading the instruction and when using the tool. If there is a discrepancy between the mental model

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[2] In a manual designed to be read linearly, the understanding of a specific chapter, depends on the user having read the chapters preceding it.

shaped when reading the instruction and the mental model shaped from interacting with the tool, the user can face difficulties in shaping a coherent model due to limitations of working memory. This is in line with Sweller and Chandler (1994), who highlight that switching between information and the tool imposes a heavy cognitive load.

Parallel to shaping a mental model about both what is read and the tool itself, the user must shape a goal, an action plan on how to reach that goal. Then monitor the result of the task execution and store information in their long-term memory for future use (Ganier 2004). Since the working memory has limited capacity, keeping all of these processes updated may contribute too much cognitive load. Weiringa, Moore and Barnes (1998) point out that stress, as well as demands on task (complexity), reduce the amount of cognitive resources that users can devote to a task (high stress levels reduce the total amount of cognitive resources that are available).

Design that supports the shaping of mental models

A central theme throughout the studied research is that a user interacting with a tool—such as a software, device or machine—shapes a mental model about it which assists them in using the tool. The concept of a mental model is used in many different contexts and has been defined in different ways (Moray 1999). Drawing from literature studied within technical communication and human-computer interaction, a mental model is, for the most part, depicted as a cognitive phenomenon the user shapes in working memory as a result of seeing and interacting with a tool. A mental model is often portrayed as something dynamic, unstable and incomplete which changes as the individual interacts with the tool. Drawing from the studied literature, a mental model is a mental representation of a tool. The representation can have a structure that corresponds to the tool. However, there are different views regarding what a mental model contains. Some scholars consider a mental model to be a representation of the structure and function of a tool. For example, Kieras and Bovair (1984) refer to a device model, which is a representation of how a device works as well as its structure and processes. Erlich (1996) and Norman (2014) refer to a user model as something the user develops in order to explain the operation of a tool. For Heiser and Tversky (2002), a mental model represents the structure and/or function of a tool. Others view a mental model as something that also contains a representation on how to

use a tool. For example, Carroll and Olson (1987), for whom the mental model tells the user how to use the tool and how it works. Karreman and Steehouder (2003), Karreman and Steehouder (2004), refer to a procedural and system model where the system model represents the internal functioning of the tool.

Karreman and Steehouder (2004) make the theoretical assumption that the user infers what steps to perform and in which order by shaping a procedural mental model in working memory. Such mental model is shaped on the basis of what the user knows and recalls as they see and interact with the tool interface. If this model is insufficient, reading an instruction in a manual is a supplementary strategy for assimilating procedural knowledge. If the instruction does not cover detailed steps, the user must infer the missing steps from a mental model on how the tool works. If this mental model is insufficient, the user can read declarative information. By reading declarative information, Karreman and Steehouder (2004) assumes that the user can shape a more comprehensive mental model of, for example, how the system works and why things operate the way they do, as compared to when they only read procedural instructions. Thus, the user can draw conclusions and infer actions that are not stated in the actual step-by-step instruction.

Having a better understanding of a tool is expected to lead to better learning when using it, specifically when it comes to transfer and problem solving (Eiriks-dottir & Catrambone 2011). However, if the mental model shaped from interacting with a tool differs from the model shaped from reading technical information, the user may face difficulties to assimilate (Ganier 2004, 2012).

Previous research assumes that technical information can support the user in shaping a mental model that aids the execution of a given work task. One stream of research has investigated the effect of procedural and declarative information on users' task performance. Another stream of research departs from the view that users shape a mental model based on their exploration of a tool. The latter research suggests that the aim of technical information is to encourage the user to explore and learn by doing. At the same time, the information design ought to support the user in their discovery so that they can shape a mental model that corresponds to the given tool. These two perspectives are studied below.

Procedural information contains stepwise descriptions about how a user can accomplish a goal. van der Meij, Blijeve and Jansen (2003), who have analysed 52 software manuals and 52 hardware manuals published between 1991-1998, conclude that procedural information is made up of goals, prerequisite states, un-

wanted states and actions and reactions. Procedural information is the most important information type in instructions for use (Karreman, Ummelen & Steehouder 2005). Declarative information, which does not directly support the actions users must execute, contains explanatory information about a tool, such as how it works, its structure, its interface and/or how to make optimal use of it.

Even though little is known about the design of procedural information (Daniel & Tversky 2012; van der Meij, Blijeve & Jansen 2003), research has shown that the way instructions are designed either facilitates or impairs the shaping of a mental model. Dixon (1982, 1987a, 1987b) showed that the reading of procedural information is facilitated when the outcome of the instruction is presented before the action statements. Instructions are read more quickly if information stating the outcome of the task is presented as an organisational overview prior to the action step, for example, 'This will be a picture of a house. Draw a rectangle with a triangle on top'. Also, action steps are read more quickly if the information about the outcome of an action is presented before the specifications of the action. For example, the sentence 'To turn on light Y, press button B' is read faster than 'Press button B, to turn on light Y'. Furthermore, the instruction is read more quickly if the action is presented before the condition for the action. That is, the sentence 'Turn the left knob when the alpha meter reads 20' is read faster than the sentence 'When the alpha meter reads 20, turn the left knob'. Regarding the formulation of actions, imperative form should be used since imperative form increases effectiveness of instructions, according to Steehouder (2012).

Guthrie, Bennett and Weber (1991) suggest that designers of procedural information should include an exposition at the beginning of an instruction (before the action steps), which contains an overview of the process, a statement of purpose and information about the outcome. Such an exposition allows users to shape a conceptual model of what they are trying to accomplish. Burnham and Andersson (1991) report that including an exposition improves the procedure of sawing a button. This is in line with Ganier (2004) who reports that users could process instructions more efficiently when the instruction contained a heading revealing the expected outcome of the procedure.

These results indicate that users first try to activate prior knowledge when shaping a mental model, visualising the outcome of the task while they read instructions. Then, they activate knowledge to shape a mental model of the action steps needed to accomplish the result. Presenting information on the expected outcome

of an entire instruction, before the action steps, then helps the user correspond what they are reading to their goals.

We know that the resolution of the action steps in an instruction—the specificity in terms of how many steps a task is divided into—has implications on initial performance as well as on learning and transfer (Eiriksdottir & Catrambone 2011). High resolution instructions improve initial performance but learning and transfer decline. Low resolution instructions impede initial performance but lead to improved learning and transfer. High resolution instructions seem to encourage users to rely on the instructions, whereas low resolution instructions require users to actively engage in the task, since they must infer the specific actions that are needed.

Information about how a tool works is the most common type of declarative information (Eiriksdottir 2011) which is called, for example, principles (Catrambone 1995; Eiriksdottir 2011), functional information (Smith & Goodman 1984) or system information (Karreman & Steehouder 2004).

Researchers have studied the effect on task performance of supplying declarative information as a complement to instructions.[3] In many studies, the declarative information are kept as texts, separate from the instructions. In other studies, the declarative information is embedded within instruction steps. Task performance results have been mixed. Some studies have shown to improve initial performance, learning and transfer whereas other has shown no improvement at all (Karreman, Ummelen & Steehouder 2005, Eiriksdottir 2011). However, previous research seems to agree that the declarative information ought to be relevant to the task at hand (Eiriksdottir 2011).

Most previous studies have been designed so that users either read procedural instructions, or declarative information or both in a training session before task performance is tested. During the task performance test, users most often lack access to any technical information. Eiriksdottir (2011) has investigated how using principles affect task performance related to troubleshooting a simulated electric circuit where different faults in a circuit must be found and repaired. Four groups of users were trained to troubleshoot the circuit with access to principles and instructions. They were then tested on their troubleshooting abilities without access

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[3] See Bibby and Payne 1993; Bibby and Payne 1996; Borgman 1999; Catrambone 1995; Eiriksdottir 2011; Karreman and Steehouder 2003; Karreman and Steehouder 2004; Kieras and Bovair 1984; Konoske and Ellis 1991; Kontogiannis and Sheperd 1999; Morris and Rouse 1985; Payne, Howes and Hill 1992; Reder, Charney and Morgan 1986; Smith and Goodman 1984.

to that information. One group of users read the principles and instructions before engaging in the training task without access to information. The second group read and summarised the principles and instructions before engaging in the training task without access to information. The third group had only access to the principles and instructions during the training task. The fourth group read and summarised the principles and instructions after the training task, and did not have access to them during the training task. Eiriksdottir (2011) found no difference in task performance related to when the principles and instructions were used. However, the group that read and summarised the main ideas in the principles and instructions before training improved declarative learning compared to the group that only read them (Eiriksdottir 2011).

Eiriksdottir (2011) also investigated whether the specificity of procedural instructions influenced how the participants used the principles. The group that used high-resolution instructions while being trained largely ignored the principles, while the group that used the low-resolution instructions read the principles. Nevertheless, Eiriksdottir's (2011) studies did not compare against users who learned from only having access to instructions.

Research on reading comprehension provides insight when it comes to understanding why declarative information have little influence on task performance. Reading comprehension research in the psycholinguistic field has found that the reader needs to have prior knowledge about the domain the text is about in order to comprehend and recall what is read (Caillies, Denhière & Kintsch 2002; Cain, Oakhill, Barnes & Bryant 2001; Elbro & Buch-Iversen 2013; Garnham & Oakhill 1996; Johnson-Laird 1983; Kintsch 1988; McNamara, Miller & Bransford 1991; McNamara & Kintsch 1996; McNamara, Kintsch, Songer & Kintsch 1996; Rawson & Kintsch 2004).

If a user does not have enough prior domain knowledge about a given tool and task, they will face difficulties comprehending declarative information since they cannot shape a mental model of the text. The user may have prior domain knowledge about the tool and task, but it may be inaccurate (thus, misconceptual). Scholars in the psycholinguistic field studying reading comprehension of anomalous data, or reading misconceptions, have shown that if there is a contradiction between what the reader knows and believes in and the text, the reader will resist to engage in conceptual change and instead stick with what they know (Kendeou & van den Broek 2005, 2007; van den Broek & Kendeou 2008). Chinn and Brewer

(1993) refer to anomalous data, meaning that if the information in a student's science text does not fit the student's theory, it is deemed anomalous. The reader will either reject, ignore or re-interpret what is read to fit it into their already shaped mental model (Chinn & Brewer 1993; Johnson-Laird 1983; Murphy & Mason, 2006). Thus, one reason why declarative information does not improve task performance, can be that the user ignored or rejected parts of the principle that contradicted their beliefs.

However, research on procedural and declarative information has not dealt with how to support the user towards finding the relevant principle in a manual containing many principles, where only some are relevant to the task at hand.

User behaviour research of novice learners suggests that information design shall guide and encourage the active user discover and explore the tool on their own (Carroll 1990; Carroll 1998; van der Meij & Carroll 1998). It is assumed that when the user is supported in doing real tasks instead of reading, they can then shape a relevant mental model which assist them in the use of the tool (Carroll & Rosson 1986). This design approach suggests that design shall enforce minimal obstruction on the users' learning-by-doing path, hence the name minimalism (Carroll 1990). This research draws upon Piaget's cognitive theory of assimilation, disequilibrium and accommodation, which assumes that individuals shape their knowledge based on their own exploration. This theoretical viewpoint asserts that the world is structured and organised in a way that makes it possible for an individual to make sense of it by discovering and exploring it on their own. This constructivist view is discussed, stating a dualism between mind and the world as emphasised by Descartes (Säljö 2013). Nevertheless, to support individuals' learning traits, four major principles (each including a number of heuristics) for the design of minimalist instructions are suggested (Carroll & van der Meij 1998):

1) Chose an action-oriented approach,
2) Anchor the tool in the task domain,
3) Support error recognition and recovery and
4) Support reading to do, study, and locate information.

Since users are depicted as interested in getting something done rather than reading about it (Carroll & Rosson 1986), design principle one and two emphasise the shaping of mental models through the performance of real tasks and not by reading declarative information. The design principle three aims to prevent the user from making errors. If they commit an error, the design should support them in

detecting (recognising and locating) the error, diagnosing (understanding the reason) and correcting it. Errors can be prevented by either placing hints in the instructions or hiding parts of a software. The heuristics for design principle four recommend not adding lengthy introductions describing how a tool works, etc. at the beginning of a manual since they only become an obstacle and hinder the user from getting started on real tasks.

The findings and suggestions of Carroll and his colleagues contradict, to some extent, the research on declarative information. For example, in Kieras and Bovair (1984) experiment number two, users who read declarative information could infer instructions better than those who inferred instructions only by exploring and discovering the device based on their pre-existing knowledge.

Minimalism is adopted in practice. Technical communicators who design minimalist manuals mostly design task-oriented topics, and conceptual information is not embedded within the task instructions but kept as separate concept topics. However, relatively little empirical research has studied the effectiveness of a minimalistic instructional design approach (van der Meij, Karreman & Steehouder 2009). Other than the experimental studies conducted by Carroll, Smith-Kerker, Ford and Mazur-Rimetz (1987) testing whether minimalism yielded better results than an expository system-oriented manual, few replication studies have been carried out on the effects of a minimal manual design (van der Meij, Karreman & Steehouder 2009). All these studies reported findings that favour minimalism, but only relative to users who used a manual design that was structured according to the functions of the system and contained more expository principles than instructions. Nevertheless, when users are in a training situation, they have the opportunity to explore, test and elaborate on different task strategies. They may not have such an opportunity when performing a work task on the job, especially in safety-critical environments, which means that the minimalistic design may not be suitable for reading-to-do on the job.

Previous research in the technical communication, human-computer interaction and psycholinguistic fields has largely focused either on users' learning behaviour when using a tool, or on the effects of different information designs, such as procedural and/or declarative information, on task performance. Research in the library and information science field has studied information behaviour, information-seeking behaviours and information-search behaviours (Wilson 1999). Very limited research could be found on searching and reading behaviours related to accomplishing work tasks using a tool. Knowledge gaps were found when it

comes to understanding what sources of information users consult and how many times users cycle between technical information (that contains instructions and declarative information covering all tasks in a tool) and the tool being used to accomplish a work task. There are also knowledge gaps regarding how users search and read within each cycle and how the task the individual is performing in the tool before searching and reading affects searching and reading behaviours, and vice versa. Altogether, this sums up to a general lack of understanding on whether or not searching and reading behaviours can become an obstacle for users as they seek to shape a relevant mental model. More knowledge is needed about the interaction between readers' cognitive system, the technical information and the tool throughout the searching and reading process. This knowledge is needed in order to inform information designers on how users' searching and reading behaviours can be taken into account when designing technical information.

2 | RESEARCH METHODS

I chose to use the Design Research Methodology (DRM) by Blessing and Chakrabarti (2009) as a guide when designing the research for this dissertation. To answer the research questions, the research work iterated between a research clarification, a descriptive and a prescriptive stage.

- The purpose of the research clarification stage, corresponding to a research clarification in DRM, is to clarify the aim and objective of the research. Related research was studied on how users search and read in technical information to accomplish a work task. Related research was studied on the design of technical information.

- The purpose of the descriptive stage, corresponding to a descriptive study in DRM, is to develop knowledge about the current situation. Empirical studies were conducted on how process operators and maintenance technicians search and read sources of information while using tools to perform a work task. The results were analysed using Vygotsky's sociocultural theory and the systemic-structural theory of activity to develop an understanding of what their tool using, searching and reading behaviours show evidence of. This stage answers research question number one.

- The purpose of the prescriptive stage, corresponding to a prescriptive study in DRM, is to elaborate on what implications the results and the analysis have for the design of technical information by technical communicators, as well as suggest a design method for technical communicators based on the knowledge developed from the current situation. This stage answers research question number two.

CLARIFYING RESEARCH

The purpose of the research clarification stage is to clarify the aim and objective of the research. The motivation for this research is the researcher's own work-life experience which is that users struggle to use technical information. Previous research was studied to find out to what extent users' difficulties had been reported elsewhere. To identify knowledge gaps worthwhile for study, literature was reviewed on how users use tools and technical information. In particular, previous research was studied on how users search and read sources of information while using tools to perform a work task, as well as research indicating the current understanding of how technical information can be designed.

Databases such as Primo, Libris, EBSCO host, ACM Digital Library, IEEE Xplore and search engines such as Google Scholar were repeatedly used to search relevant research articles.[4] Articles were reviewed by first reading the abstract, and then the conclusions. The bulk of relevant research was found within the technical communication, human-computer interaction, information science and psycholinguistic research fields. The studied research is presented in the section titled Related research.

UNDERSTANDING THE CURRENT SITUATION

The purpose of the descriptive stage is to develop knowledge about the current situation. Knowledge about the current situation serves as a reference point since the design method suggested in the prescriptive stage aims to improve aspects of the current situation. Knowledge about the current situation also serves as a reference for future studies evaluating how the information design, as a result of following the suggested method, influences the current situation. I chose to divide the work to answer research question number one into two steps:

Step 1: Develop knowledge on how process operators and maintenance technicians search and read sources of information while using tools to perform a work task.

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[4] Search queries were formulated using boolean combinations of keywords such as "technical communication", "information design", "information-seeking", "information behavior", "reading behavior", "seeking behavior", and "sociocultural theory".

Step 2: Analyse the results using Vygotsky's sociocultural theory and the systemic-structural theory of activity to develop a deepened understanding of what their tool usage, searching and reading behaviours show evidence of.

Developing knowledge on how process operators and maintenance technicians search and read

The purpose of the first step is to develop knowledge on how process operators and maintenance technicians search and read sources of information. This was accomplished through collecting and analysing empirical data and conducting a composite sequence analysis to develop a composite sequence of their tool using, searching and reading behaviours. Work tasks requiring them to use tools in order to perform them, were viewed as the contexts in which they searched and read. Empirical data was collected and analysed over the course of two studies. An ethnographic research method was selected. The observations were structured, as the researcher had defined a framework to guide what would be observed during empirical data collection. The observer alternated between functioning as a complete observer to (only occasionally) acting as an observer-participant. Observational interviews were conducted where applicable.

The purpose of the first empirical study was to investigate how process operators interact with a tool and technical information. Five Swedish males, ranging in age from 31 to 65 years, were observed in a laboratory while they performed a number of pre-defined tasks in the context of operating software to control the production of liquorice. The software was previously unknown to them. The following research question was asked: Do software users display patterns of documentation behaviour that may warrant further, more formal, investigation? The unit of analysis was the interaction behaviour with designed technical information in relation to the task being performed with the tool.

The only information available to the participants in the laboratory was the printed user manual. This user manual was designed according to contemporary technical communication design guidelines by the researchers who are experienced technical communicators. What pages were relevant to each exercise was defined, as well as the sequence of action steps required to accomplish the exercise. Prior to being observed, participants were asked to imagine that they themselves were responsible for controlling the production of liquorice in a process industry where they could act freely to carry out as many of the pre-defined tasks as possible.

Rather than thinking aloud, they were asked to verbalise their thoughts on what information they felt they needed as soon as they turned their attention to the printed user manual for assistance. Only the participant and the observer were present in the laboratory. Every session was recorded (audio and video) and key types of behaviour were noted by the observer. The software was set up to automatically log user interactions in separate text files for each exercise. The behaviours collected via notes from each observation, together with video recordings and log files were coded on a spreadsheet. The observed behaviours were coded into one of two sequences of interaction: interaction with the tool or interaction with the manual. The outcome of each sequence of interaction with the tool was rated by performance (success or failure). The pages the participants read were compared against the pages defined to be relevant and further categorised as either relevant to the task (+) or not (-). The type of behaviour in each sequence of interaction was classified. The vocalised information need was classified according to De Jong and Ferguson-Hessler (1996) taxonomy of knowledge types. A detailed account of the data collection and data analysis method is presented in paper A. The result is patterns of behaviour on the sequences, participants employed when using, searching and reading.

The purpose of the second study was to investigate maintenance technicians' information-seeking behaviours. Seven Swedish maintenance technicians were selected to participate in the study. One was female, and six were male. They were responsible for corrective and predictive maintenance work tasks in a repair centre for machines taken out of service. One of the six male maintenance technicians was a team leader. The observed maintenance technicians were all moderately or highly skilled at performing maintenance assignments. The ages of the maintenance technicians ranged from 23 to 63 years, averaging 41 years. Six participants had completed high school education; one had completed elementary school. At the time of this study, the participants had worked as maintenance technicians between four months and 14 years, averaging six years. The following research questions were asked: What types of information needs do maintenance technicians show evidence of? Where do they go to satisfy these needs? An ethnographic research method was selected. Participant observation was selected to collect data. A conceptual framework on how maintenance technicians were assumed to seek information was developed (see paper B for the first version), with the aim of guiding what to observe during empirical data collection.

The study develops knowledge on what information needs maintenance technicians show evidence of and what sources of information they select. Although the first empirical study revealed interesting patterns of behaviour, it was delimited to a controlled laboratory environment. The second study focused on behaviours in individuals' working environment. Maintenance technicians were selected because it was assumed that they seek information periodically as part of fulfilling their everyday work tasks. The study was not limited to searching and reading behaviours in designed technical information, but also included the sources the participants preferred. Literature in information science was studied to understand how maintenance technicians and similar types of roles, such as engineers, seek information. Limited previous research on their information-seeking behaviour could be found. Systemic-structural theory of activity and Byström and Hansen (2005) task-based information-seeking framework were selected to synthesise a framework. The unit of analysis was information needs and sources of information. An observation sheet was developed and tested to record the observed behaviours. The observer would alternate between functioning as a complete observer to (only occasionally) acting as an observer-participant, in accordance with Baker (2006). The observations were coupled with observational interviews, as Katz (2002) suggested. The raw data from the observations were transferred to a spreadsheet and cross-checked against the observation sheet to ensure that all records had been transcribed. The recorded information source hosts and physical information object were analysed, and each given a post-observation code in Swedish. The type of question word used at the beginning of recorded verbal queries was analysed. The classification of question words in Andersson (1993) was used to give each query a post-observation code. For every recorded query expression and searched physical information object, the work task was analysed as an activity system to analyse types of information needs. An activity system comprises the goal and the object of the work task, which was identified by analysing the ethnographic field notes. Data about the work task context was collected via the ethnographic field notes. The post-observation codes assigned during analysis were recorded in Swedish and then translated into English once the analysis was complete, in preparation for communicating the results to others. Paper E outlines the detailed method for data collection and analysis.

The empirical data from the two studies was analysed using a composite sequence analysis, following Miles, Huberman and Saldaña (2013). Data from mul-

tiple participants was extracted to develop a composite sequence display that represents common and unique features in meaningful sequences and paths. The unit of analysis is the searching and reading process. Empirical data from the two studies was first condensed by giving the observed actions post codes signifying a process action. Then, codes were grouped to develop second-order pattern codes signifying common patterns.

Analysing tool using, searching and reading behaviours

The purpose of the analysis is to gain deeper understanding of what the observed tool using, searching and reading behaviours show evidence of. This is from the point of view on how cognitive functions, tools and behaviour interacted when the participants executed work task using tools and technical information. A deeper understanding can be gained by looking beneath surface behaviours to find out what is really going on. A theory-driven suspicious approach was used. A suspicious approach presupposes that the observed behaviours are merely the surface-level manifestations of the underlying processes and structures that generate them (Willig 2014). Observations are not to be taken at face value (hence the reference to suspicion) and instead are used as clues which point to a more significant, latent meaning. What was observed is thus not the whole story, but merely the tip of the iceberg. An interpretation is supported by assumptions the interpreter makes about what is important and what is worth paying attention to, as well as what can be known about and through the data. In other words, the interpretation I generate, depends upon the ontological and epistemological positions I adopt before commencing the process of interpretation. So, in order to gain a deeper meaning from an account it was necessary to have access to theoretical concepts, as they provide the lens through which the data is interpreted.

The selected theoretical concepts provide a way to declare (for the reader of the interpretation) what ontological and epistemological positions I took prior to analysis. Furthermore, how I define the used theoretical concepts is essential since how I come to interpret the empirical results rests on my interpretation of the chosen theoretical concepts. I use the theory proposed by Vygotsky on the development of higher psychological functions (Cole, John-Steiner, Scribner & Souberman 1978) and the systemic-structural theory of activity (Bedny & Harris 2005; Bedny, Seglin & Meister 2000) to analyse the empirical results. These theories are relevant since, throughout the process of using the tool, searching and reading,

previous research has shown that users read signs, such as icons in a software interface or words in designed information, in order to understand their meaning and to then plan how to use a tool based on what was understood. The literature on information-seeking and reading comprehension was studied to gain a deeper understanding of behaviours that Vygotsky's sociocultural theory and the systemic-structural theory of activity does not specifically address. Such literature was mostly found in the information science and psycholinguistic research fields.

SUGGESTING A DESIGN METHOD

The purpose of the prescriptive stage is to elaborate on what implications the results and the analysis have for the design of technical information by technical communicators, as well as suggest how technical information can be designed to increase process operators and maintenance technicians' chances of accomplishing a work task using tools. This stage answers research question two. I chose to perform this stage by iterating through three steps:

Step 1: Elaborate on what the desired situation is, and pinpoint what it is about the current situation that prevents the user from reaching the desired outcome.

Step 2: Conceptualise how the user could be better supported by design in order to reach the desired outcome.

Step 3: Realise parts of the conceptualisation by designing the support and conducting initial evaluations.

One purpose of the first step is to elaborate on what the desired situation is. The departure is the analysis, providing a deeper understanding of what the observed behaviours in the current situation show evidence of. This step also elaborated on what it was in the current situation that prevented the user from reaching the desired outcome, and what needed to happen in order to reach the desired outcome. From these elaborations, the implications for the design of technical information by technical communicators were identified.

The purpose of the second step is to conceptualise how the user could be best supported by design in order to increase the likelihood of making what needs to happen, happen in the journey towards the desired situation. It is the technical

communicator who designs this support. Therefore, this step develops, what Blessing and Chakrabarti (2009) refer to as the intended support. I used Vygotsky's sociocultural theory on how thought and action are mediated through the presence of a mediating agent, in this case, the psychological tools. As per Kozulin (1998) psychological tools are human-made cultural artefacts that help individuals master their psychological functions and behaviour. Psychological tools can be different types of signs, words in a text, formulae, charts, diagrams, maps, etc. The intended support both addresses the method on how to design the support as well as what the expected outcome is.

The purpose of the third step is to realise parts of the intended support through the design of technical information. Technical information for two types of tools were designed; one supporting the use of the liquorice machine used in the first empirical study and one supporting the use of a software. In the third step, initial evaluations of the realised technical information were made by studying individuals acting as users to test whether or not they can use and make sense of it. The individuals were asked to use the technical information and imagine themselves in an industrial setting performing a work task. They independently used the support and explored the tool, and afterwards, were asked by the researcher about what they could and could not understand. After each evaluation, what was learned was fed back into the development of the intended support. The purpose was to develop the intended support in iterations by reflecting and following an action inquiry cycle according to Tripp (2003). The realisation of the intended support is however not what Blessing and Chakrabarti (2009) refers to as the actual support. For them, the actual support is, for example, instructions, guidelines and other support for the designer on both how to design and what the outcome of the design work is. Such actual support was not developed, nor tested on technical communicators, in the prescriptive stage. The realisation of the intended support was neither evaluated on process operators or maintenance technicians when they performed a work task.

METHODOLOGICAL REFLECTION

In this section, I motivate why I have designed my research as I have and discuss alternative methodologies for consideration. I present how I have worked to ensure trustworthiness and how I have considered ethical aspects. I will also address the aspects of the population, selection of participants and transferability.

I have sought to learn, understand and illuminate a phenomenon in a specific setting and, from such understanding, suggest how to improve aspects of it. I have tried to develop knowledge from learning about situations in which individuals act, related to how the phenomenon of interest unfolds naturally. Therefore, overall, I have selected a qualitative research approach, in line with Patton (2015). The approach to first obtain an understanding of the current situation, and then to suggest how to improve it by design, is influenced by design research methodology (Blessing & Chakrabarti 2009). One reason why I selected this methodology as a guide is that it emphasises thoroughly obtaining an understanding of the current situation before focusing on designing something. Obtaining such an understanding, which is to frame what problems there might be, reduces the risk of becoming fixated on the idea that the reason why users are not supported by designed technical information is solely due to the design. Another reason is that its perspective provides a way to define what the purpose of design support is. Design is a support that aims to improve the current situation towards the desired situation. The methodology emphasises that in order to identify what a desired situation might be, one must first understand the current situation. Yet, another reason is that this approach is relevant for defining what aspects to evaluate when evaluating technical information design. Understanding how a suggested design influences the current situation and whether it improves it or not, can only be evaluated by having an understanding of the current situation.

Blessing and Chakrabarti (2009) state that it is the designer's current situation that is to be understood—that is, the way designers carry out the design work and how different factors influence the process. With the intervention of design support addressing certain factors, the result of the design process will be improved in the direction of the desired outcome. If there is a lack of knowledge on the designer's current situation, the researcher needs to conduct empirical studies within the descriptive study to obtain an understanding. In this dissertation, sufficient knowledge on the designer's current situation is deemed available, since in previous research of technical communication it's reasonably clear that technical communicators need to understand user behaviour in order to design technical

information that can function as a support. Since not enough knowledge on user searching and reading behaviour could be found, the purpose of the descriptive study is to understand the current situation of the users of a design while using a tool and technical information in a work task. Based on an understanding of the user's current situation, a design method is developed, aimed at technical communicators. The suggested method also aimed at uncovering what the expected outcome is of following the design method. The design method equals what, in the design research methodology, is referred to as the intended support.

Future studies could develop the actual support as, for example, guidelines for technical communicators which is a realisation of the intended support. Such guidelines could then be used to evaluate how the design outcome of technical communicators' design work influence process operators and maintenance technician's current situation. Knowledge from such evaluations could be fed back into the development of the intended support and then, if the desired situation is not accomplished, the whole design process is iterated. These latter steps of developing the actual support and evaluate it are not within the scope of this dissertation.

Nevertheless, the researcher ends up having dual roles if they are developing the actual support, following it to design the technical information, and evaluating the designed technical information. According to Coghlan and Brannick (2005), dual roles—in this case being a researcher and a technical communicator—introduce the risk of role confusion and ambiguity. A dual role situation could negatively influence trustworthiness since a researcher's preconceptions, plus the fact that they must maintain both closeness and distance may be distorted through conscious or unconscious misinterpretation.

Another approach to design research could be to iterate through a process of understanding the characteristics of a specific user group in terms of what they say they need or require, formulating a design idea, and evaluating the design on (or with) users. The final step in this process would entail learning what worked or not. And then the entire process would repeat until a design that satisfies the needs are reached according to an action inquiry cycle, as depicted by Tripp (2003). Such an agile or rapid prototyping approach was not selected as it has too strong a focus on the desired situation compared to the current situation.

Yet, another approach could be an action design research approach, where prescriptive design knowledge is developed through building and evaluating artefacts

together with end-users in their organisational setting. One such approach is reflected in the action design research method proposed by Sein, Henfridsson, Purao, Rossi and Lindgren (2011) which contains stages and principles related to formulate the problem, build, intervene and evaluate, reflect and learn, and formalise learning. Such an approach is interesting but was not selected either. This is because, to some extent, it would be based on users' accounts of what they believe the current and desired situations are, rather than on observations of how the users behave.

Furthermore, I could have started by studying existing contemporary designs of technical information from the assumption that the difficulties professionals report facing relate to the design. Then analysed to what extent current designs follow principles in document design derived from research. In case of deviations, I could have re-designed the technical information and evaluated the difference it made on users' work task. Such an approach was not selected as there is a risk that the research work would jump too quickly into designing something before gaining a deeper understanding of the current situation.

 An ethnographic method was selected to learn and understand the current situation. I decided to collect data mainly through the observation of behaviours (coupled with observational interviews) I anticipated would be present. In order to avoid influencing trustworthiness, I chose not to rely heavily on methods that depend on participants recalling their own behaviours, such as interviews or questionnaires. The reasoning was that individuals might be more likely to report what they think happened rather than what actually happened (Eager & Oppenheim 1996). Bedny, Seglin and Meister (2000) also state that individuals may be unaware of many tasks and actions they perform. Thus, participants may not be able to accurately recall how they used a tool or how they searched and read information in order to accomplish a work task.

However, there are several aspects of the present research that may jeopardise the trustworthiness of the results obtained regarding the kinds of observations and analysis performed. This is because, in qualitative research, the researcher is the instrument (Patton 2015). Furthermore, in qualitative research data collection and analysis are inevitably a rather subjective state of affairs. One aspect of being an instrument is that the researcher influences the studied phenomena when participants are aware that an observer is present. Moreover, the researcher is present with participants when implementing designed artefacts in the participants' setting, and the participants know that the researcher is the designer. Another problematic

aspect is that the researcher's preconceptions can influence the observer to either perceive events that did not occur or to miss events that did in fact occur. The latter aspect is also present when analysing data. This is because individuals are known to pay attention to events that correspond with their own beliefs and knowledge, while ignoring those that contradict them (Chinn & Brewer 1993). Since trustworthiness depends on the ability and effort of the researcher (Golafshani 2003), I have taken measures to minimise negative influence on trustworthiness.

In the first empirical study, one measure taken to increase trustworthiness was, besides observing and taking notes on an observation sheet, to also document behaviours via film and audio recordings for later analysis. Furthermore, each click the user performed in the tool interface was logged. These methods were used to enable cross-checking of behaviour across multiple data sources in case of doubt during analysis. Since information needs are a cognitive phenomenon that cannot be observed, participants were asked to verbalise what information they needed as they were searching in the manual. Moreover, participants were not compensated for their participation, other than receiving a box of liquorice (which they only became aware of after participating). Participants knew that the researcher who observed them is a technical communicator, and they knew that the researchers had designed the technical information they used. However, the participants were not in a position of dependence in relation to the researcher. Nevertheless, the researchers were careful not to expose any beliefs or assumed outcome which could influence participant behaviour.

In the second empirical study, one measure taken to increase trustworthiness was to randomly select the days the maintenance technicians would be observed. To ensure trustworthiness when developing knowledge on the types of information needs the maintenance technicians exhibited, a conceptual framework was constructed in which the behaviours assumed to be linked to the indication of an information need were defined. This is because the concept of an information need is viewed as a cognitive phenomenon which is not possible to observe. To construct a trustworthy framework, the systemic-structural theory of activity as well as Byström and Hansen's (2005) framework was used, both of which are based on empirical studies. Then, only the activity system actions defined in the framework as being evidence of an information need were observed.

Another measure taken to ensure trustworthiness in the second empirical study was open-ended, observational interviews. These were conducted to gain clarification whenever an expressed query was unclear or whenever it was unclear which information the maintenance technician had deemed to correspond with a query. Additionally, no record was kept in cases where the observer found it difficult to tell whether an object used to retrieve information could be considered a tool or not, or where it was difficult to tell whether or not an object could be considered to be a source of information. The method used for analysing information needs was assumed to negatively influence trustworthiness in cases where a behaviour, such as a query expression, was analysed without considering the context. In order to avoid jeopardising trustworthiness, ethnographical notes about each work task context were kept during observation. The notes were then analysed during the information needs analysis. In this study, the researcher had not designed any of the technical information the maintenance technicians used. The researcher was careful not to expose any beliefs or assumed outcome, which could influence the participants' behaviour. The maintenance technicians were not compensated for their participation.

The purpose of analysing the results of the two empirical studies was to develop knowledge on what the observed behaviours might indicate. Since I am aware that the two studies differed in terms of participants and their setting, I avoided making the analysis imply a coherent set of behaviours. This would have weakened trustworthiness. Results from the two different settings allowed similarities and differences to be highlighted and revealed users' areas of difficulties in which a design support could be fruitful.

Another aspect that may appear to weaken the trustworthiness of the analysis is the use of Vygotsky's sociocultural theory to analyse results from a laboratory study. However, the aim of the analysis was to gain a deeper understanding of how thought and language influence —and are influenced by —searching and reading behaviours, as well as the task behaviours in a tool. How the participants behaved and thought during observations depended on the social contexts in which they acted prior to the observations. However, the social context at the time of the observations is not necessarily something that the analysis needs to consider. Nevertheless, to ensure the trustworthiness of an analysis, an analysis needs to be transparent about why and how a theory is used, which theoretical concepts are used and how they are interpreted.

The following measures were taken to ensure a reasonable balance between the protection of individuals' privacy in order to avoid exposing them to unnecessary harm, and the quest for knowledge which can only be gained if research participants are exposed to a certain degree of risk. Informed consent was requested verbally to allow each participant to decide on their participation. Each participant was also briefed about the purpose of the study, but not to an extent that the researcher's assumptions and expectations were revealed. The participants were informed about how data would be analysed, published and stored. Confidentiality was promised but not anonymity. One aspect that can influence participants' privacy is that the collected data from observations and interviews were not checked with them afterwards. Furthermore, I considered whether an ethical review was necessary. Such a review was not required since I determined that the studies would not harm participants' physical or mental health.

When selecting a population to study, instead of pinpointing certain user groups, I chose to centre in on situations where humans perform professional work tasks and are likely to search and read in order to learn how to use a tool. The work tasks of process operators and maintenance technicians were determined to represent the situations in focus. To select participants for the first study, a request was sent out to a large number of individuals who were considered to possess the characteristics of process operators. To select participants for the second study, a request was sent to five randomly selected industrial companies in the Mälardalen region of Sweden, which were determined to employ such maintenance technicians. From this perspective, this dissertation does not aim to specifically develop knowledge about process operators or maintenance technicians, but situations in which humans perform such professional work tasks and search and read technical information. The small sample size does not cater for transferability; or to a discussion on the extent to which the results can be generalised to apply to the work role of process operators or maintenance technicians. Furthermore, since the first empirical study was performed in a controlled laboratory environment, that is, away from participants' natural work task setting, I can only claim that the results are valid for the current participants, context and design. I cannot make claims that the observed behaviours happen elsewhere since that would not be trustworthy.

3 RESULTS

This chapter provides an overview of the results obtained from over 90 hours of observations of process operators and maintenance technicians' tool using, searching and reading behaviour.

HOW INDIVIDUALS INTERACT WITH SOFTWARE AND TECHNICAL INFORMATION

The results of study number one (see paper A) show how five participants, ranging in age from 31 to 65 years, searched and read a user manual in order to use a piece of software in a laboratory setting. The software was a tool for controlling the fictitious production of liquorice. The empirical material consists of audio and video recordings, notes from the observer and a software interaction log.

The five participants were asked to perform 15 exercises each. Each observation session lasted between 40 minutes and two hours. Altogether, the participants initiated 59 exercises and successfully completed 51. In eight of the exercises, participants gave up after having tried. In 37 exercises, they consulted the user manual to find information. In each of these occurrences the participants sought and read one or more pages in the user manual before then returning to the software. A combined documentation behaviour was counted as starting whenever participants stopped interacting with the software and started to search and read the user manual. A combined documentation behaviour was counted as ending whenever they stopped searching and reading and returned to interacting with the software. Within a combined documentation behaviour, participants could shift their attention to look at the software interface. When ending a combined documentation behaviour to interact in the software, they could shift their attention and look at a page on display in the manual, as when following a procedure.

In total, participants exhibited 104 combined documentation behaviours. In 15 of the 37 exercises, they exhibited one combined documentation behaviour to complete the exercise. In 22 of the 37 exercises, participants exhibited an average of four combined documentation behaviours to complete the exercise. Participants would try using the software, get stuck and seek information only to repeat the cycle. The cycle would repeat until they either completed the exercise or abandoned it. Participant number two performed nine combined documentation behaviours to accomplish exercise number two. All participants but one returned to the same page in the manual that they had consulted in a previous combined documentation behaviour as they attempted to complete the same exercise. In 20 of 37 exercises, participants consulted the manual directly after having read the task exercise without first using the software. In contrast, participants were able to accomplish 14 exercises without using the manual.

In total, the participants viewed 148 pages in the user manual throughout 104 combined documentation behaviours. They returned to the table of contents to look up another page or browsed to another page. The software, task exercise and user manual were designed so that all the information which the researchers deemed relevant and required for completing the exercises correctly could be found in the user manual, but (especially for later exercises) not necessarily all in one page. Following 54 of 104 combined documentation behaviours, when returning to interact with the software, the participants did not follow the sequence of steps they needed to follow in order to progress towards accomplishing the exercise. In about two-thirds of these non-successful interactions, participants had read one or several of the pages the researchers had defined as relevant for the exercises. Almost a third of the 148 pages they read were not among those the researchers had defined as relevant for the exercises.

In the study participants showed a strong preference for procedural information, even when satisfying non-procedural information needs. In about half of the instances where an information need was verbalised prior to searching and reading in the user manual, the need was procedural in nature. Almost without exception, when participants turned to the manual for the first time when carrying out a particular exercise it was to look for procedural information. For instance, participant number one in exercise two said, "In this situation, I need information that tells me how I activate temperature and the others as well". In the second combined documentation behaviour, when participants were dissatisfied with the

procedural information or the result of applying it to the task at hand, the information need was often expressed in conceptual, strategic or situational terms. However, the topic they selected as a candidate for meeting their non-procedural information need did not always contain non-procedural information. In one-third of the occasions where a non-procedural information need was expressed, the participants tried to meet the need by consulting a topic containing procedural information.

INFORMATION-SEEKING BEHAVIOUR AMONG MAINTENANCE TECHNICIANS

The results of study number two (see paper E) reveal what information needs seven maintenance technicians, ranging between 23 and 61 years of age, showed evidence of and what sources of information they selected in a repair workshop while performing work tasks. In this study, the empirical material consists of data collected from participant observations (recorded on observation sheets and in field notes). The observed maintenance technicians showed evidence of 50 different types of information needs. They selected four different types of sources of information.

The observer spent 12 working days, or 85 hours total, in the repair centre, with the time spread out evenly across 12 weeks. Thus, each maintenance technician was studied for approximately two working days.

At the time of the study, 14 employees were working in the selected repair centre facility. Of these 14 employees, 12 were employed as maintenance technicians. Seven of the 12 maintenance technicians were selected to participate in the study. One was female, and six were male. One of the six male maintenance technicians was a team leader. Of the remaining seven employees who were not observed, two were managers, and five were field technicians who were constantly out of the office, on-site with customers.

The observed maintenance technicians were all moderately or highly skilled at performing maintenance assignments. They received regular, in-house training because they worked for the same company that manufactured the machines being serviced. Six participants had finished high school and one had completed elementary school. At the time of this study, they had worked as maintenance technicians

between four months and 14 years, averaging six years. The maintenance technicians seldom worked together on the same work task. If they did, it was usually for very short periods of time. They knew one another well and had no problem helping each other.

In order to later analyse the types of information needs the maintenance technicians indicated and what sources of information they selected while performing work tasks, each observed occurrence of an information-search task was noted. With each occurrence, data was collected on what sources of information were selected, what queries the maintenance technicians expressed when asking a human such as a colleague, and what information they looked up in a resource (denoted as a physical information object) when not asking a human. A total of 146 information-search tasks were observed which yielded 146 unique information needs, classified into 50 types of information needs.

The results of the study revealed that the maintenance technicians selected four different types of information sources (denoted as information source hosts), which have been classified as human, analogue artefact, digital artefact and natural phenomenon. For each recorded information-search task where a query was expressed to another human, the information source host was classified as a human type. An analogue artefact information source host type could be, for example, a binder containing printouts or a notepad with handwritten notes. In the study, many physical artefacts, such as machines or boxes of spare parts upon which physical information objects had been attached in the form of a metal nameplate or sticker, were classified as information source hosts of the analogue artefact type. In cases such as these, the serial number on the nameplate was classified as a physical information object of the analogue human artefact type, and, correspondingly, the machine was also classified as an analogue human artefact information source host type. Furthermore, in the study, physical artefacts, such as machines, were classified as an information source host of the natural phenomenon type. For example, the physical information object might be an electrical impedance (the complex ratio of voltage to current in an alternating current circuit) or the movement of a wheel, which both reveal something about the status of a machine.

The study results show that the maintenance technicians expressed seven different types of queries to a human as a colleague. Of the 82 recorded queries that were expressed to a human information source host, 39 began with a question word that was either an interrogative pronoun or an interrogative adverb. A question word is used to indicate a question that calls attention to a referent that is

unknown to the inquirer but assumed to be known by the one being asked (Andersson 1993). Six different types of question words were used; thus, the 39 recorded queries were labelled as: What, How, Where, Who, Why or When queries. These types of queries (for example, "How do I perform task X?") were categorised into a broader category named Explorative, since the maintenance technicians were not formulating questions to which only confirmation was sought. By contrast, 38 queries began with an auxiliary verb. Five auxiliary verbs were used, including: Have/Has, Do/Does, Can, Is, and Shall—as in, "Shall we go here?" Such queries were analysed and found to constitute alternative questions, as described by Andersson (1993), and were thus categorised as Confirmative. The grammatical construction of these queries was found to indicate that the maintenance technician had, essentially, already formulated an answer for which only confirmation was sought. In addition, five other queries were categorised as Confirmative, even though they did not begin with an auxiliary. One such query started with 'if', but later included an auxiliary. In two records, the auxiliary verb was omitted, but an analysis of the grammatical construction deemed it to be Confirmative. For example, maintenance technician A posed the following question to a colleague: "Björn got help, right?" (which would equal "Did Björn get help or not?").

The results show that the maintenance technicians searched 23 different types of physical information objects, distributed across 64 recorded information-search tasks.

THE COMPOSITE SEARCHING AND READING TO DO SEQUENCE

The composite sequence display, which can be viewed in figure one is the result of a composite sequence analysis of the empirical material from both the laboratory study and the field study. This display serves to contribute a fuller understanding of the participants' behaviours.

Participants exhibited two types of task behaviours. One type was executing work in a sequence of steps, such as assembling a machine. The other task behaviour was seeking information in sequences of steps. The participants in the two studies sometimes carried out work tasks without performing any information-seeking tasks. The opposite was never observed.

Each observed participant carried out several work tasks. A single work task was counted as starting whenever a participant in study number one began reading the instructions for the exercise, and counted as ending whenever they began reading the instructions for the next exercise. A single work task was counted as starting whenever a participant in study number two read a work order and initiated work on a machine, and counted as ending whenever they began reading another work-order and initiated work on another machine as stated in the order.

Each observed participant carried out several information-seeking tasks. An information-seeking task comprises the steps involved in selecting a source of information, searching it and then reading what was found. What is denoted as a combined documentation behaviour in study number one, equals an information-seeking task in the composite sequence display. An information-seeking task was counted as starting whenever participants stopped executing steps in the work task in order to execute the steps involved in seeking information. An information-seeking task was counted as ending whenever they stopped seeking and turned their attention to executing steps in the work task.

A participant would begin a work task (see arrow a in figure one) by first executing work in a sequence of steps using tools, such as an electrical measurement device and then shifted to performing an information-seeking task (see arrow c in figure one). They also, at times, started work tasks by first performing an information-seeking task (see arrow b in figure one) and then shifted to executing work in a sequence of steps (see arrow f in figure one). The results from study number one show that when the participants consulted the user manual, they performed, on average, four information-seeking task to accomplish a work task. The maintenance technicians seldom displayed more than one information-seeking task behaviour when accomplishing a work task.

When a participant initiated an information-seeking task, they selected a source of information. The participants in the laboratory study only had the printed user manual available for selection.

When searching, the participants used a search tool, such as a table of contents, index or search engine to locate a page containing, for example, an exploded diagram of a machine. In a few instances, the maintenance technicians were observed to use a source of information that did not include a search tool, or chose not to use the one included. For example, the participants in the laboratory study would open up a page in the manual without looking in the table of contents first.

Once they had located such a page, it was observed that they looked at the information; an action which was determined to be a reading task (see arrow d in figure one). The information they retrieved was displayed on a page containing all the text and images (either on paper or a digital screen), without necessitating a search. In over half of information-seeking tasks, the maintenance technicians selected to ask a colleague, and the answer they received was sufficient enough that they did not have to search elsewhere.

Once having read the found information, the participants were observed to return to searching another page (see arrow e in figure one). Participants in both studies were also observed to search by browsing to another page without first using the search tool. The participants in the laboratory study looked up an average of 1.42 different pages throughout their information-seeking task, which could indicate that seeking information is not as straightforward as locating the needed information on the first search and read cycle.

The maintenance technicians were observed to select another source of information after having first searched and read pages in the initially selected source of information. This indicates that the maintenance technicians were unable to find what they needed in the source they initially selected.

While reading, the participants in the laboratory study could be observed to shift their attention to look at the tool interface and then return to reading. Once having read the found information, the participants were observed to return to executing steps in their work task (see arrow f in figure one). While executing the steps with the tool, the participants could shift their attention and look at a page on display in the manual, as when following a procedure (see arrow g in figure one). The participants in the laboratory study would often look up the same page within the same information-seeking task. They were also observed to look up the same page over the course of different information-seeking tasks within the same work task. Additionally, the maintenance technicians were observed to look up the same page but across seeking tasks in different work tasks.

At times, it was observed that the participants in the laboratory study were unable to accomplish a work task. But in such a case, they would stop while executing steps in the work task and not while searching and reading. This indicates that they did not have difficulties finding the information they considered relevant once they started to seek.
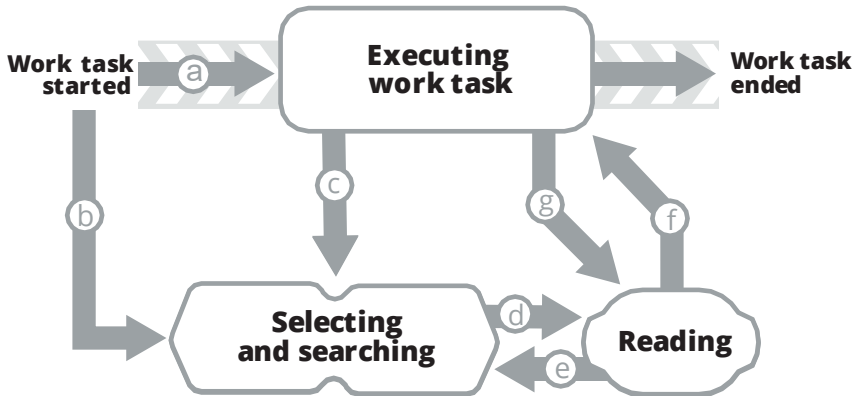
Figure 1: Composite display showing the observed participants' work and information seeking task process. The boxes represent a sequence of action steps. The arrows represent the shift in focus from one sequence of action steps to another. A participant started a work task by first executing work in a sequence of action steps and then performing an information seeking task. They also, at times, started work tasks by first performing an information seeking task in order to then execute work in a sequence of action steps. An information seeking task comprises the action steps involved in selecting a source of information, searching it and then reading what is found. Once having read the found information, the participants were observed to return to executing action steps in their work task.

4 | THEORY AND ANALYSIS

The task behaviours in the empirical material are analysed in order to gain a deeper understanding of what they show evidence of. The analysis illuminates how cognitive functions, tools and behaviour interacted when the participants executed work task using tools and technical information. The analysis reveals, for example, why some participants could accomplish a work task after searching and reading technical information while others could not.

I use the theory proposed by Vygotsky on the development of higher psychological functions (Cole, John-Steiner, Scribner & Souberman 1978) and the systemic-structural theory of activity (Bedny & Meister 1997), to analyse the empirical results.[5] Vygotsky's theory, hereafter referred to as Vygotsky's sociocultural theory, is selected due to it's ability to explain how individuals learn and develop cognitive and task abilities through the mediation of psychological tools in sociocultural activities. I selected the systemic-structural theory of activity because it builds upon Vygotsky's sociocultural theory to explain how cognition and task behaviour interact when an individual tries to accomplish a goal using a tool.[6] The interpretation of the selected theoretical concepts from Vygotsky's sociocultural theory is primarily based on the reading of Cole, John-Steiner, Scribner and Souberman

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[5] These theoretical perspectives are chosen since I believe that mind, behaviour and the environment in which humans act are related and one of them cannot be studied without considering the others. I also selected these theoretical perspectives since they contribute to understanding aspects of user behaviour in design, as it has not, to the researcher's knowledge, been previously used within technical communication research. Both Vygotsky's sociocultural theory and the systemic-structural theory of activity are viewed as part of a sociogenetic theoretical perspective in line with Gavelek and Whittingham (2017). Theories such as sociolinguistics and social semiotics build on the same theoretical views and hence can be viewed as part of a sociogenetic perspective.

[6] The systemic-structural theory of activity builds on the general theory of activity, which originates in the works of Rubinshtein, Leont'ev, Bernshtien, Anokhin, and Vygotsky (Bedny & Karwowski 2004). The theory is specifically tailored to the study of work (Bedny & Karwowski 2003) since it explains goal-directed activity from a psychological perspective where the individual is the agent of the activity.

(1978), Vygotskij (1934/2001), Cole (1999), Kozulin (1998, 1999, 2003), Wertsch (1985) and Säljö (2013). The interpretation of the selected theoretical concepts from the systemic-structural theory of activity is primarily based on the reading of Bedny and Meister (1997), Bedny, Seglin and Meister (2000), Bedny and Harris (2005), Bedny and Karwowski (2004), Bedny and Chebykin (2013), Bedny and Meister (1999), Bedny and Karwowski (2003).

To gain a deeper understanding of what the observed task behaviours show evidence of, I analyse the empirical results according to the theoretical concepts of goal, task, task plan, action step, technical tool, psychological tool. Literature on information-seeking and reading comprehension was searched and studied to gain a deeper understanding of the behaviours that Vygotsky's sociocultural theory and the systemic-structural theory of activity does not specifically address.

EXECUTING STEPS IN A WORK TASK

All participants executed work in a sequence of steps which are analysed as the performance of a task. A task can, according to Bedny and Chebykin (2013), be explained as cognitive and motor behaviours performed for the purpose of satisfying a need by accomplishing a goal in a specific activity system.[7] Following Bedny and Meister (1997), the participant's execution of tasks show that the intensity of the need that motivated them to engage in the task, had to be proportional to the perceived effort of reaching the goal. Figure two shows the relationship between a need and a goal.

As part of the task performing process, participants shaped a task goal, which is analysed as the future desired state of an object. For the maintenance technicians, for example, a machine was the object of the work task. A machine was

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[7] Needs are in this dissertation viewed in accordance with Bedny and Meister (1997). They state that needs are associated with the self: for example, self-preservation, food and shelter, love of family, self-recognition, feeling of worth, and, on an abstract level, concern for the society. However, needs do not directly trigger activity. Needs are a future desired state, which is better than the current, but there is no clear view of how to satisfy a need. If the individual can consciously imagine specific objects that can (directly or indirectly) satisfy his or her need, then they may engage in an activity. The image of the future object becomes the goal. The individual becomes motivated to engage in an activity, if the effort to accomplish the object is in proportion to the intensity of the need. Bedny and Meister (1997) call needs, motives when they generate human activity towards accomplishing certain goals. Motivation is thus a source of energy that drives the activity. However, motivation to engage in an activity may not only derive from needs, but also from intention, aspiration, attractions, sets, desires, strivings or similar.

transformed from an initial state, such as disassembled, to the desired state, such as assembled. A goal has been analysed to consist of what Vygotskij (1934/2001) refers to as thought and inner speech. What goal the participants shaped in working memory depended on what knowledge they recalled from long term memory when planning how the need could be satisfied. What knowledge the participants had developed in long term memory, depended on what they had learned and internalised throughout their experience participating in sociocultural activities in particular activity systems.

The artefacts participants used during the execution of task steps are analysed as tools.[8] They used two types of tools. In the study of the maintenance technicians, a specialised screwdriver used to unscrew screws on a machine, has been analysed to equal what Wertsch (1985) refers to as a technical tool. In the first study of participants operating a liquorice machine, the production control software is analysed as a technical tool. In relation to the body, technical tools have an outward direction since they transform the object of the task (Wertsch 1985). The second type of tool the participants used has been analysed to equal what Cole, John-Steiner, Scribner and Souberman (1978), Wertsch (1985), and Kozlyn (1998) refers to as a psychological tool. In relation to the body, psychological tools have an inward direction since they influence the development of higher mental functions (Cole, John-Steiner, Scribner & Souberman 1978). The maintenance technicians were, for example, observed reading a diagram showing an exploded view of a machine. The diagram is an example of a psychological tool, as a thought representing the machine and its parts is shaped in working memory when reading it. In this case, the maintenance technicians did not have to memorise how the different parts of the machine fit together. These two types of tools co-existed, as the user interface of some of the technical tools had psychological tools imprinted.

In study number one, the participants looking at the technical tool interface were classified as 'Studying the ALPC 342's interface'. Following analysis, it was determined that when looking at the technical tool and interacting with it, the participants were recalling domain knowledge from long term memory. When recalling knowledge, they shaped inner speech and thought about the technical tool.[9]

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[8] A tool is defined here in line with Cole (1999), as a cultural artefact, such as an electrical measurement device, a blowtorch, a piece of software or a binder containing print outs, made by humans in particular activity systems.
[9] The thought and inner speech the participants shaped, relate to the concept mental model in the technical communication and the human-computer interaction literature. The concept of a mental model is discussed by for example Carroll and Olson (1987), Erlich (1996), Karreman

The shaped thought and inner speech told the participants, for example, how the technical tool worked, what parts it consisted of, how the parts were related and how the technical tool should be used. Following analysis, it was determined that the thoughts and inner speech the participants shaped depended on their domain knowledge which, in turn, depended on what they had learned and internalised from using similar tools in previous sociocultural activities.[10]

The thought and inner speech the participants shaped, intertwined with the process of shaping and accepting the work task goal and planning the task. This is because what future desired states of objects were possible depended on what technical tools they had available or expected to have access to. In certain work tasks, the participants executed action steps and in a later step in the sequence, they located and started using a technical tool. The analysis is that they could shape a thought about the technical tool during goal formulation without having to first look at the tool.

The action steps the participants executed, for example clicking in the menu of a piece of software, are analysed as steps in a task plan. By following Bedny, Seglin and Meister (2000), such a task plan is considered to be a thought in working memory on how the goal can be accomplished (see figure two). The task plan is shaped before executing action steps. The participants used inner speech to plan what steps to perform in the technical tool in order to transform the object of the task from the initial state to the desired state.[11] The task plan informed the participants of what they could expect to see as they performed steps in the technical tool. Drawing upon Bedny, Seglin and Meister (2000), the content of the task plan depended on what domain knowledge the participants recalled when looking at the tools, as well as on their development stage for the task. A task plan is viewed to equal what Karreman and Steehouder (2004) refer to as a procedural mental

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and Steehouder (2004), Kieras and Bovair (1984), Norman (2014) and Heiser and Tversky (2002).

[10] The design of the tools probably also constrained what thoughts and inner speech the participants shaped. Norman (2013) discusses that the design of everyday things, in terms of what controls are visible and how they are mapped as well as the feedback mechanisms will influence the mental model the user is shaping. The design of a tool in terms of how controls are mapped, what feedback it gives, its affordances suggesting the range of possibilities on how to execute a task, and the constraints which limit the number of task alternatives, will influence what domain knowledge the user recalls when interacting with it.

[11] Studies in the human-computer interaction field on user behaviour highlights that users are interested in throughput (Carroll & Rosson 1986). Novice users trying to learn a new software, assimilate what they see into what they know and start to act even if they know that their knowledge is insufficient.

model. In line with their reasoning, if the participant lacked the knowledge needed to shape a coherent task plan, they tried to infer the missing steps from knowledge on how the technical tool works.

Each step the participants executed in a task plan are analysed as a combination of cognitive and motor behaviour. In each action step, the participants shaped an action-goal which means that they expected a certain outcome from performing the step. When the participants executed an action step, the technical tool responded by entering a new state (see figure two). For example, the software the laboratory participants used displayed a dialogue containing psychological tools. When the participants read the new technical tool state, they recalled knowledge which gave rise to thoughts and inner speech to explain what they saw. In accordance with Bedny and Harris (2005), the participants evaluated the thoughts on what they saw according to how well those thoughts corresponded to the expected result. When the new state turned out as expected, as formulated in the action goal, the participants continued to execute the next action step in the task plan.

At times, it was observed that the participants had to redo the same step but slightly differently, which drawing upon Bedny, Seglin and Meister (2000) shows evidence of a self-regulation process.[12] Such a self-regulation process is considered to occur if the thoughts shaped from the new state are evaluated to not match the expected state. Or, if the participant was unable to recall the knowledge needed to shape a thought about the new technical tool state.[13] In this case, participants used inner speech to self-regulate the task plan. Figure two illustrated the self-regulation process. According to Bedny, Seglin and Meister (2000), individuals modify a task plan in order to execute modified steps until the result is evaluated to correspond with what is expected or satisfactory.

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[12] Research in Human-computer interaction has shown that learners spend 25 to 50 % of their time correcting errors (van der Meij & Carroll 1998). This research defines types of errors, such as semantic errors (totally wrong method to reach a goal), syntactic errors (the method is correct but executed incorrectly, that is, – some steps are in reverse order, they do not hit hard enough), and slips such as keystroke errors.

[13] This relates to what Norman (2013) refers to as the gulf of execution and gulf of evaluation. However, Norman (2013) does not deal with the concept of self-regulation when depicting the stages of action. Considering self-regulation, it means that gulfs of execution and evaluation could only occur if an individual cannot self-regulate due to the fact that they cannot recall any knowledge when seeing the tool state.

After having executed a number of steps in sequence, the maintenance technicians started to do something else, at times in a different location. It was interpreted that they had performed the steps in the task plan and evaluated the final state of the object to be satisfactory since it equalled the work task goal. In this case, the need motivating them to execute the work task was satisfied.
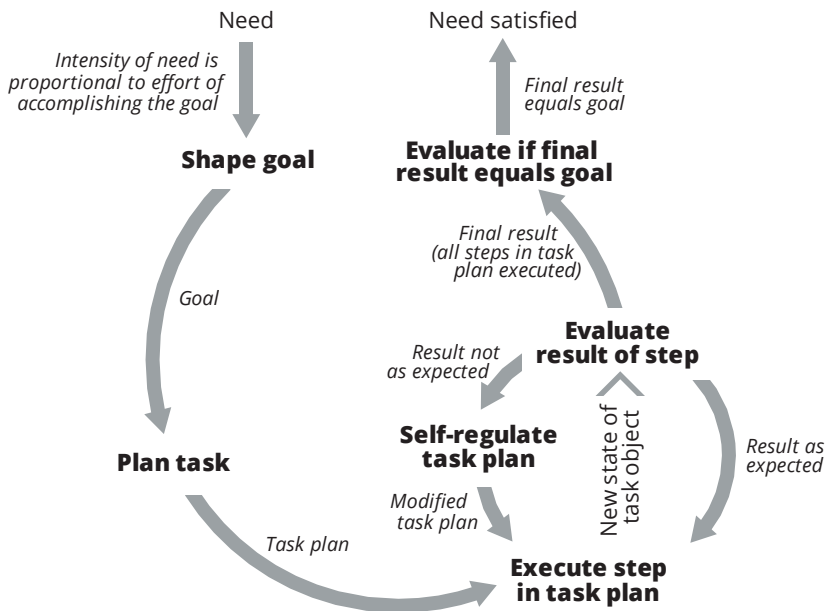

Figure 2: Simplified model of the different task stages of the observed participants' work tasks. Text in bold represents different task activity stages which are cognitive and motor behaviors. Text in italics represents a result of a cognitive task stage. The simplification using arrows may imply a rational and linear behavior, which was not always the case.

SEEKING INFORMATION

The participants in the two studies sometimes selected and used sources of information. The content of such sources was analysed to consist of psychological tools. In over half of the exercises in the laboratory study where participants consulted the user manual, they directly started to seek and read in the user manual after reading the exercise.[14] The maintenance technicians also sought and read in sources of information before executing action steps in a work task. This behaviour serves as evidence that the participant could not shape either a work task goal or task plan, and sought information to be able to do so.[15]

In less than half of the exercises in which laboratory participants consulted the user manual, participants went to the technical tool to execute action steps directly after reading the exercise. Many times, they then executed action step sequences that were not among those the researchers had defined as necessary for accomplishing the exercise. This shows that the participants had shaped a goal that could not be accomplished or a task plan that could not lead to goal accomplishment. Since goals and task plans are shaped before action steps are executed (Bedny, Seglin & Meister 2000), their goals and task plans were analysed to not correspond with the technical tool. Since goals and task plans are shaped by recalling knowledge on what results can be accomplished, it was analysed that these participants had a misconception about the technical tool. The participants then stopped executing action steps, at times after having self-regulated the task, and shifted focus to seeking information and then returned to performing a step.

The analysis illuminates three reasons why the participants stopped executing action steps and started to seek information. Firstly, when looking at the new state after having executed a step, they could not recall the knowledge needed to shape thoughts that explained what they saw. In such a circumstance it becomes difficult to evaluate the relationship between the new state and the expected outcome. Another reason is an evaluated mismatch regarding the outcome of the action. They could shape a thought about the new state, but it did not match what they expected to see.[16] A third reason relates to the execution of proceeding steps in the task

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[14] What is denoted a combined documentation behaviour in the laboratory study is, in this analysis, denoted an information-seeking task.

[15] Technical communication research discusses to what extent users consult documentation – see, for example, van Loggem (2014).

[16] Norman (2013) refers to the mismatch between what an individual expects to see after a task step and what is viewed as the gulf of evaluation.

plan. When the result of a certain step was evaluated to match what was expected, they could not execute the next step in the task plan. This occurred when the new state and the proceeding steps in the task plan did not match. Perhaps they could not find a menu item in the software, expected something to exist in a certain location, or the tool asked for input that they did not recognise.

When seeking, the participants carried out a number of action steps, which are analysed as steps in an information-seeking task. The information-seeking task consists of different task stages. A certain need triggered the participants to engage in an information-seeking task. It was analysed that the need was to become more knowledgeable so that they could self-regulate the work task goal or plan. Such a need can be referred to as the concept of information need in the information science literature.[17] The maintenance technician showed evidence of 50 different types of information needs (see paper E).

It was analysed that in order to satisfy a need, the participants shaped an information-seeking goal. Such a goal was analysed as a future desired situation, in which they knew what steps to complete in order to accomplish a work task goal, or had understood the new state of a tool, or had resolved the mismatch between what they saw and what they expected to see. As participants executed a sequence of action steps while seeking, they formulated a task plan on how to reach the information-seeking goal. In the analysis, the sequence of seeking action steps are grouped into two subtasks where each subtask includes the task stages:

- A search task, and
- A reading task.

This grouping is in line with Byström and Hansen's (2005) task-based conceptual framework. However, in their framework, an information-seeking task consists of an information-search task and an information use task. Their information use task equals what is, in this analysis, denoted as a reading task.

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[17] Within the field of library and information science, information need is complex concept that has intrigued scholars for decades (Cole 2011). The work of Belkin, Oddy and Brooks (1982) and Wilson (1981) has influenced the information science view of information needs. According to Belkin, Oddy and Brooks (1982), an information need is a cognitive phenomenon arising from an anomaly in the user's state of knowledge related to some topic or situation. According to Wilson (1981), an information need is a secondary need, as a consequence of primary physiological, cognitive, and affective human needs which arises due to such things as the user's social and work roles.

SEARCHING INFORMATION

It was observed that the maintenance technicians selected a source of information to search.[18] This was analysed as they used inner speech to shape a task plan on how to locate the preferred source of information, and how to search it. Prior to shaping a search task plan, participants shaped an information-search goal. Their information-search goal was analysed as a future situation in which they have retrieved the desired psychological tools, for example, an instruction on how to perform a task. The psychological tools are the object of the information-search task. The participants used inner speech to formulate what psychological tools they desired. Desired psychological tools are those that eventually give rise to the thoughts and inner speech, needed to accomplish an information-seeking goal. When the participants in the laboratory study consulted the manual for the first-time they vocalised a need for procedural information. Thus, it was analysed that they knew that the desired psychological tools existed in the manual, even though they had never used it previously.

In the maintenance technicians' repair workshop, there were other sources of information that they did not select, which was interpreted as indicating they preferred the selected source over others (see paper D). This behaviour is in line with Savolainen (2008) who states that individuals are knowledgeable about which sources of information are available in their environment. Savolainen (2010) states that individuals use source preference criteria to decide which source to select. In half of the observed search tasks in study number two, the maintenance technicians consulted a colleague which means that a colleague was seen as a preferred source of information.

Many of the questions the observed maintenance technicians asked colleagues were categorised as confirmative (see paper E for details).[19] Such behaviour indicates that they were seeking confirmation whether their thought was correct or not. For example, this could happen when they were shaping a thought about what the new state of the tool meant, but had become uncertain.[20]

The participants were observed to execute action steps, such as looking in the table of contents of a manual, entering keywords in a search engine, or browsing

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[18] The participants in the laboratory study were not selecting a source of information, as the environment was controlled so that they would only have access to one source of information.
[19] In the study of maintenance technicians, what referred to in this dissertation as psychological tools was then referred to as physical information object.
[20] Such behaviour relates to confirmation bias in psychology.

papers in a binder, in the source of information they had located. In these search tasks, the desired psychological tools were embedded in the source of information, such as a text in a product database. When shaping a search task plan, the participants exhibited the use of inner speech to plan on how to retrieve the desired psychological tools from the located source. The user interface of such sources consisted of psychological tools organised according to a certain architecture. Once they were read, the participant shaped thoughts and inner speech. Such thoughts informed the participant about, for example, what information the source contained, how it was structured and how it was used. In some of the maintenance technicians' search tasks, the selected source of information had a search engine which meant that they had to express external speech that was appropriate for the source in order to make it retrieve the desired psychological tools.[21] When they executed the task plan, the information source changed its state. Psychological tools, in the form of for example a text, became visible as a response.

Only in very few cases were the maintenance technicians observed to select another source of information after having searched the initial one selected. This indicates that they did not find the desired psychological tools in the first selected source.

READING AND EXECUTING STEPS IN THE TOOL

All participants, at certain time, looked at a retrieved text—which is analysed as a reading task.[22] When the participants read the psychological tools making up a text on a page, they recalled knowledge to shape thoughts. Scholars within the psycholinguistic field such as Johnson-Laird (1983) and McNamara, Miller and Bransford (1991) discuss that readers shape a mental model of the text they read. The mental model shaped when reading a current sentence is integrated into the mental model shaped as a representation of the whole text. McNamara, Miller and Bransford (1991) refer to the latter as a working mental model and the former as a passage

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[21] Thoughts, inner speech and external social speech are separate cognitive processes, however interlinked (Cole, John-Steiner, Scribner & Souberman 1978). To shape external speech as a representation of thought and inner speech, relates to semiotic generalisation, or the symbolic functions of a language.

[22] The reading comprehension literature discusses different types of reading goals. The reading goal of the observed participants in this dissertation relate to Gunnarsson's (1989) reading goal knowing how to act.

mental model. According to scholars in psycholinguistic research, such as Garnham and Oakhill (1999), the reader must bridge sentences by making inferences to shape a mental model when reading.

In this dissertation, the concept of mental model discussed by scholars in the psycholinguistic field, is interpreted to relate to what Vygotskij (1934/2001) refers to as thought and inner speech. Depending on the thought and inner speech shaped from reading, it allowed participants to comprehend what the text was about. It is probable that the participants continuously used inner speech to evaluate to what extent the thoughts shaped from reading could accomplish the information-seeking goal. The empirical material indicates that, at times, the participants did not read the complete text on a page. This behaviour was analysed to mean that they stopped reading as soon as they had evaluated that their information-seeking goal had been accomplished. Then, the psychological tools they read had to equal those desired, thus, fulfilling the information-search goal.

The participants in the laboratory study read a certain text on one page, then browsed to another page which was read for a longer or shorter period of time.[23] They self-regulated the search task plan to retrieve other psychological tools. At times they went back to a page containing a text they had previously looked at within the same information-seeking task. In the laboratory study, an average of 1.42 different pages were read within one information-seeking task (see paper A), and there were cases when they looked at more pages. The maintenance technicians were not observed to retrieve and read several pages within one information-search task.

The behaviour of reading one page and then searching and reading another is analysed to indicate that they could not accomplish the information-seeking goal from reading the first page alone. One reason is that the participant could not recall the knowledge needed when reading the psychological tools on the first page to shape a thought and inner speech. Or, they lacked domain knowledge to make inferences to bridge sentences. Thus, they could not comprehend. Nevertheless, at times they could probably shape thoughts and inner speech from reading. Then, another reason why they discarded the page they read might be that the thoughts they shaped were evaluated to not equal the information-seeking goal. The reason for looking up a page that was later evaluated to be irrelevant, could be attributed

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[23] Some scholars in the psycholinguistic field state that readers skim read or read strategically before they read a text in depth (see for example Dreher & Guthrie 1990). In this dissertation, skim-reading behaviour could not be distinguished.

to a lack of knowledge on what type of information the source of information contained and how that information was labelled and structured. Participants found an entry in the table of contents and read the corresponding page, to discover that the text was not what they expected it to be. Another reason for looking up a page that is later evaluated irrelevant could be related to how external speech is expressed. If a source of information requires an individual to express keywords to retrieve information, the individual must shape external speech to represent the information-search goal. If an individual constructs external speech that is not representative of the information-search goal, they may end up retrieving information that is not relevant to it. However, the empirical data does not include observations of information-seeking tasks where participants expressed keywords and retrieved non-relevant information.

At a certain point during searching and reading, the participants shifted focus. They turned their attention back to the technical tool to execute the step they stopped prior to searching and reading. Certain participants shifted back and forth between the text and the technical tool, as when executing steps one by one in a procedure. As they shifted focus to the technical tool, their behaviour indicated that they had accomplished the information-seeking goal. The participant knew what steps to perform, comprehended the new state of the tool or object, or had resolved the mismatch between what they saw and what they expected to see. Such a result indicates that the participants did not have difficulties finding information which they evaluated to be relevant.

The laboratory study shows that in over half of the instances where participants returned to the technical tool to execute steps, they did not follow any of the sequences of action steps the researchers had defined as required in order to progress towards accomplishing the exercise. In two-thirds of these occasions, they had read one or several pages that the researchers had defined as relevant to their exercise. The maintenance technicians did not show evidence of the inability to progress after seeking information. For some exercises in the laboratory study, the instructions needed to accomplish the exercise were distributed across several step-by-step lists on different pages. Analysis indicates that one reason why the participants study could not progress after having read a page that was relevant was due to their reading behaviour. Scholars in the psycholinguistic field have shown that the knowledge a reader has recalled and the mental model they have shaped prior to reading, influence reading behaviour. The reader will try to fit what they have read to the mental model they had already shaped from reading previous

passages in the same text (Anderson & Pearson 1984; Goodman 2014). If the reader is later asked what they have read, they remember the mental model they shaped (Garnham & Oakhill 1999). Scholars in the psycholinguistic field, studying reading comprehension of anomalous data, or misconceptual reading, have shown that if there is a contradiction between the text and what the reader knows and believes, the reader will stick to what they know and resist to engage in conceptual change (Kendeou & van den Broek 2005, 2007; van den Broek & Kendeou 2008). Chinn and Brewer (1993) refer to anomalous data, meaning that if the information in a student's science text does not fit the student's theory, it is anomalous. The reader will either reject, ignore or re-interpret what is read to fit it into their already shaped mental model (Chinn & Brewer 1993; Murphy & Mason 2006).[24] Such scholars report that the mental model shaped before reading acts as a frame and establishes expectations on what the text is about. Johnson-Laird (1983) states that the reader tries to find evidence that would override or contradict the shaped mental model. If such evidence cannot be found, the reader is satisfied with the existing mental model.[25] This is in line with Ganier (2004) who notes that a contradiction can arise between what users see in a tool and what they read about it.

Since the participants in the laboratory study, in most cases, had used the technical tool prior to searching and reading, they already shaped thoughts about it prior to searching and reading. For example, regarding how they assumed the technical tool worked, how it was used and how the new state as a result of an action was understood. However in 54 of 104 seeking occurrences when returning to the technical tool, participants did not follow the sequence of steps required to accomplish the exercise. This indicates that they had misconceptions about the technical tool. If what they then read did not fit their expectations or contradicted their thoughts shaped prior to reading, it was analysed to indicate that they ignored or rejected what they had read. Ignoring or rejecting certain parts of the text had implications on the possibility to shape a relevant task plan.

In the laboratory study, the participants searched and read pages that the researchers had defined as irrelevant to the exercise in about one-third of the information-seeking tasks (see paper A). However, it is analysed to indicate that the participants evaluated those pages to be relevant since they returned to interaction with the technical tool. Analysis illuminate that one reason could be due to the

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[24] This is in line with Carroll and Rosson (1986) who state that the user is likely to stick to what they believe in. Thus, a user is more likely to assimilate rather than accommodate.
[25] Johnson-Laird (1983) refers to the phenomenon as satisficing.

previously described reading behaviour. The participants tried to fit what they read into a previously shaped thought, while they ignored or rejected parts of the text that contradicted it. In this case, they understood the text as saying something it did not.

Another reason relates to how relevant participants' sequence of steps was to the exercise at hand. In half of the instances that the laboratory participants returned to the technical tool, they did not follow the sequence of action steps required for accomplishing the exercise. If the participants then searched a page that was relevant to their misconceived sequence of steps, the page was not relevant for the exercise. In such a case, neither their information-seeking goal or information-search goal were relevant to the work task.

An information-seeking task was analysed as ending whenever the participants stopped searching and reading, and shifted to execute action steps with the technical tool. If they could not accomplish a work task step after having sought and read technical information, the participants in the laboratory study either gave up or performed a new information-seeking task until the work task goal was eventually reached. In the laboratory study, the participants performed on average four different information-seeking tasks to accomplish an exercise. This show evidence that self-regulation of the work task goal or work task plan after having accomplished the information-seeking goal did not enable participants to progress in the task. The maintenance technicians were not observed performing several information-seeking tasks in the same or another source of information in order to perform a work task. This could be explained from the perspective that the maintenance technicians were in the later stages of the zone of proximal development for the work task they were performing. The respondents in the laboratory study who were novices at using the technical tool were, on the other hand, in the early stages of the zone. Thus they had to resort to consulting more support in order to accomplish the work task. Participants in both studies were also observed returning to reading the same text they had read in a previous information-seeking task. This indicates that the same text can be used to accomplish different information-seeking goals. As participants in the laboratory study performed exercises, they seemed to learn the technical tool as they could later perform exercises with fewer information-seeking tasks, compared to earlier exercises (see paper A). In eight exercises in the laboratory study, participants could not accomplish the exercise and gave up.

5 | DESIGN SUGGESTION

In this chapter, I present the implications for the design of technical information. Based on the implications, I put forward a suggestion for how technical communicators can design technical information for tools to increase process operators and maintenance technicians' chances of accomplishing a work task in industrial settings. The overall suggestion is based on the view that the purpose of technical information is to support the user in shaping goals which are possible to accomplish with a technical tool and task plans that lead to the accomplishment of a goal. Here, a user refers to an individual who uses advanced technical tools which they have not fully learned while performing work tasks on the job. The technical tool is an important part of their work role responsibility and used on a frequent basis.

The analysis illuminates that executing a sequence of action steps that did not correspond to the required sequence was caused by participants' misconceptions about what results could, and must be, accomplished in the technical tool. In other words, if the user lacks relevant knowledge of what results are possible in a technical tool, they may shape work task goals that are not possible to accomplish. Or, they may shape task plans that will not lead to the accomplishment of their goal. Following analysis, such misconceptions explain why the participants searched and read pages that were not relevant and why they could not self-regulate towards executing the correct sequence of action steps after reading relevant pages (see chapter Theory and analysis). In order to execute the correct sequence of action steps, the user needs to shape work task goals that can be accomplished and task plans that lead to the accomplishment of a goal. This is because goals and task plans are shaped before action steps are executed. The analysis illuminates that work task goals and action steps in a task plan equal results in the technical tool which the user desires to accomplish. Powering a machine unit on or off is an example of a result.

The first implication for the design of technical information by technical communicators is that they need to provide support to users in order to enable them to shape a thought about what results are possible to accomplish when using a given technical tool. This is to increase process operators and maintenance technicians' chances of accomplishing a work task using tools.

The second implication is that this support should not be embedded within technical information where the user must search and read in order to find it. This is drawn upon the analysis which illuminate that a user's knowledge of a technical tool—and what results can be accomplished—influences whether they can be supported in accomplishing a work task through searching and reading technical information. If a user has little knowledge on what results can be accomplished or if they have misconceptions, meaning their knowledge does not correspond with the technical tool, they either cannot shape goals or task plans—or the ones they do shape are not possible to accomplish in the context of their work task. The risk increases that they will search and read a page that is relevant to their non-relevant goal and task plan and misunderstand the relevant pages.

The suggested design method on how technical communicators can provide support to increase process operators and maintenance technicians' chances of accomplishing a work task, is informed by theoretical concepts from the psychological theory proposed by Vygotsky on learning and development of higher psychological functions. The suggestion is that technical communicators design tangible tokens that signify the results which are possible to accomplish using the technical tool, as well as a scaffold supporting the arrangement of the tokens into a result model. [26] As the user reads the scaffold to learn what the tangible tokens signify and how to arrange them into a result model, and then arranges the tokens themselves, their thought on what results are possible is mediated. Thereby, the user is in a better position to shape relevant work task goals and task plans. The tangible tokens function as psychological tools. In Vygotsky's sociocultural theory, psychological tools are human-made cultural artefacts that help individuals master their psychological functions (Kozulin 1998).

The suggested method was developed by iterating in a process of prototyping, evaluating and re-designing tangible tokens and a scaffold. In the following sections, I first present the suggested design method, then I present the theoretical

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[26] Seel (2006) distinguishes three approaches when discussing how individuals can be supported in the construction of a mental model for learning: self-discovery, guided-exploration or scaffold-learning. The suggested design method equals scaffold-learning.

concepts I have chosen, explain why I have chosen them, and how they inform the suggested design method.

The suggestion is that the technical communicator iterates through a four-step process.[27]

1. Identify the various results that are possible to accomplish in the technical tool, as well as the components that generate them.
2. Design tangible tokens signifying each identified result and corresponding component.
3. Design a scaffold to support the user in arranging the tangible tokens into a result model.
4. Design information that addresses users' information needs.

The design can be evaluated by observing representatives from the target audience as they arrange the tangible tokens into a result model while using the scaffold instruction. Complete the four steps in an iterative process until reaching a point where the targeted users are able to arrange the tokens into a valid result model.

STEP ONE - IDENTIFY THE RESULTS

The first step is to identify the various results that are possible to accomplish, as well as the components that generate them within the technical tool.

View a result as something small or large, digital or analogue, that can be experienced (viewed, heard, sensed or smelled) in a technical tool interface as a consequence of triggering the hardware or software functionality. A result can be, for example, the creation of something that did not exist before such as liquorice candy. Changing the state of a hardware or software functionality, such as by powering a unit on or off, is another example of a result (given that the new state can be experienced). Such results are meaningful for the user since they satisfy a need they have which motivated them to use the technical tool in the first place.

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[27] The technical communicator constructs a mental model of the technical tool from which they design the psychological tools and the scaffold. Norman (2014) refers to this model as the designers' conceptual model. As the psychological tools are defined as technical information, they can be (by drawing upon Norman, 2014) viewed to part of the technical tools system image. Relating to Seel (2006), the psychological tool is a design and instructional model (or [DIM(CM(S)]) which is a representation of the designers' conceptual model.

While developing the design method, it was found that it is also necessary to identify the component that provides an identified result. A component is a hardware or software functionality that generates the result when it is triggered by the user or an external event. Identifying the components was found necessary in order to allow the users to understand what a result signifies.

When identifying results, the suggestion is to begin by viewing the whole technical tool as a component and identify the main results it can accomplish. For most technical tools, there are many possible main results that can be accomplished. Select one result to begin with and identify the intermediate results that typically must be accomplished along the process of accomplishing the identified main results. Then, identify the components that generate the intermediate results and identify the action step that triggers the component to generate the result.

When modelling the results and components, also identify the dependencies between results. This is because the dependencies reveal the sequence of action steps the user must execute in order to accomplish a result. A dependency between results is a case where a result generated from one component is the input for another component. In such a case, the result from a certain component is refined by another into something new. Consequently, it may mean that in order to accomplish a certain result, certain other results must have been priorly generated in a certain sequence. Thus, with the results and their dependencies as a starting point, the sequence of action steps for how to accomplish a result can be designed. The result of the first step is a list of components and their results, as well as the dependencies between results.

STEP TWO - DESIGN TANGIBLE TOKENS

The second step is to design tangible tokens that signify the components and their results, as identified in step one. The suggestion is to design one tangible token for each identified component and each result as, for example, a symbol on paper (see figure three for an example). On each component token, add a label signifying the name of the component. For each result token, add a label signifying what the result is. If the size of the token allows, add a picture to support the user in understanding what physical correspondent the tangible token signifies.

Since one component usually consist of several subcomponents, use different sizes for the component tokens to allow the user to place smaller component tokens onto their parent. This allows the user to learn the relationship between components. Use one type of shape for the tangible tokens signifying components, another shape for results. Use the same colour for a component token and its corresponding result. Using sizes, shapes and colours support the user while building the complete model to help them recognise and distinguish what belongs together.

To make the dependences between results visible, state the result that needs to be accomplished before another given result can be accomplished, on a label on the backside of the token, for example. This way, if the user flips the token, they can read what the dependency is.

STEP THREE - DESIGN A SCAFFOLD

The third step is to design a scaffold that supports the user in building a result model of the tangible tokens. There could be different ways to scaffold the user. The suggested way is to design information (in a certain modality such as a text and images) that consists of both an overview part and a step-by-step part. The overview part describes the goal of following the scaffold, and the overall steps required to accomplish it. The overview could also highlight the typical activity system, such as an industrial setting, in which the technical tool is typically used, for example, by displaying an image of the setting. From such an image, the user can recall domain knowledge in order to shape a mental model of the setting. Next, the technical tool could be introduced in terms of its purpose in such a setting, as well as the main result it is designed to accomplish. However, the overview part should not display an illustration of what the expected result is of following the scaffold, since the user might try to arrange the tangible tokens as a copy of the illustration, which impairs learning.

In the second part, introduce each of the intermediate results and their corresponding components step by step, according to the sequence in which they must be accomplished in order to reach the main result. When introducing the components, explain what the component is and its purpose, in order to signify the component in the world. For example, if a result is a signal generated by a regulator, tell the user what a regulator is, and its purpose within the context of generating signals. As such, the scaffold describes the structure and functionality

of the technical tool, similar to the examples given by Heiser and Tversky (2002). Next, give the user all the tangible tokens of components and results in random order and ask them to build a result model by reading the support in the scaffold (see figure three). Within each step, ask the user to select the tangible tokens they believe signify the introduced result and component, and then place them into the result model.

To build a result model, the user must recall knowledge about the type of tools the technical tool represents. As the user re-arranges tangible tokens in a self-regulation process, their thought is mediated and they shape a mental model representing what they are building. This way, the user is scaffolded in learning about what results can be accomplished in the technical tool.

Throughout the mediating activity, users' possible misconceptions can be refuted. If they have misconceptions about the tool, they may place the tangible tokens in the wrong order. Or, if they do not read the entire support information in the scaffold and ignore or reject parts of it, they may end up not being able to place certain tokens in the model. The suggested method of arranging a result model from tangible tokens, makes a user's possible misconceptions or lack of technical tool knowledge rise to the surface. By showing a correct placement of the tokens at the end in the scaffold, the user is given feedback on what placements they have made that are not correct, which allows them to engage in conceptual change. This approach follows research in the psycholinguistic field which has shown that highlighting a contradiction in the text, can refute readers' prior knowledge and enable them to engage in conceptual change (see for example Chinn & Brewer 1993; Guzzetti, Snyder, Glass & Gamas 1993; Kendeou & van den Broek 2007; Murphy & Mason 2006). However, the scaffold and the tangible tokens should not be designed in terms of shape, colour and size, so that the user can arrange them in the correct order just by focusing on these characteristics, without having to consider what they signify.

Once the user has built a result model by arranging the tangible tokens, they have shaped a mental model of the technical tool. If they manage to internalise the tangible tokens, they have developed new knowledge. The individual's knowledge is developed as they move from intramental to intermental, from socially regulated behaviour to self-regulated behaviour (Gallimore & Tharp 1990). When such knowledge is recalled as they later execute action steps in the technical tool, it will mediate their shaping of goals and task plans. However, if the tangible tokens are not internalised after having arranged the result model, new knowledge is not

developed. In such a case, there is a risk that the user will be unable to shape thoughts on goals and task plans that correspond to the technical tool later on when executing action steps. Having the result model available to read during action step execution will mediate their thoughts so that they can self-regulate the goals and task plans towards accomplishing a goal.

Nevertheless, the user themselves select when to seek information in technical information. The technical communicator should try to motivate the user to engage in the activity of building a result model as early on as possible (before using the technical tool or before seeking information). This is to mitigate the risk of the user shaping a thought on what results they think can be accomplished through their own exploration, which does not correspond the technical tool.

Since the tangible tokens and the result model built by the user are viewed as technical information, the user is the one organising the technical information into a structure—not the technical communicator.

STEP FOUR - DESIGN INFORMATION ADDRESSING USERS' INFORMATION NEEDS

A user may need information when executing action steps in the technical tool which cannot be obtained from the built result model. For example, information on what something in the graphical user interface in the technical tool signifies, where a menu command is located in the interface, or how much the technical tool weighs. In this case, the technical communicator needs to design additional information addressing the user's information needs. A fourth step aims to design such additional information. However, it is not in the scope of this dissertation to suggest the details on how to design technical information addressing user's information needs. Nevertheless, some ideas are provided.
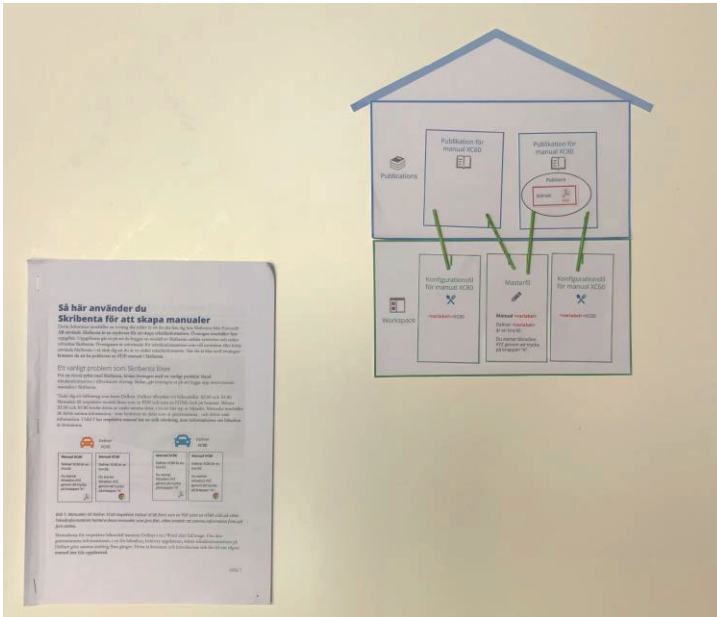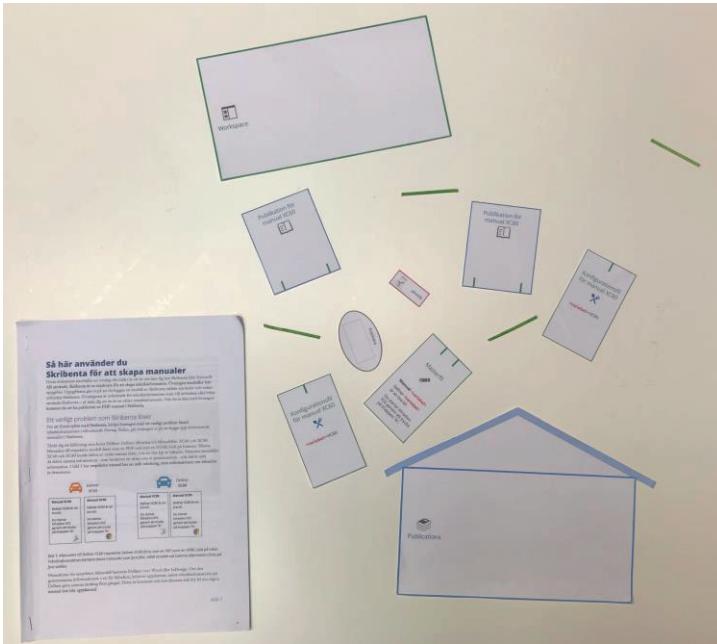
Figure 3: The above most photo shows the tangible tokens given to the user in a random order prior to the mediating activity. The photo below shows the result after a user has arranged the tokens to build a result model by being supported by a scaffold instruction. Photograph by J. Lundin.

One type of information could serve to gather all of the action steps required to accomplish a certain result. When designing such instructions, it is recommended that technical communicators depart from the result dependences identified in step one. Another type of information is conceptual information about the component, other than that which is provided in the scaffold. Such information could describe where the component is located in the technical tool, what it looks like, and technical data, for example. The designed information could relate to a component or its result. This allows the user to find the designed information based on recognising the tangible tokens. This way, the user can find additional information from the built result model.

THEORETICAL CONCEPTS

The theoretical concepts from Vygotsky's sociocultural theory on the learning and development of higher mental functions were used to inform the work of suggesting the design method. The theory is used, for example, by scholars in educational psychology to design school learning curriculums. The concepts I have selected to inform the design of technical information relate to how the presence of a mediating agent, in this case, the psychological tools, mediate thought and action. As per Kozulin (1998) psychological tools are human-made cultural artefacts that help individuals master their psychological functions. Psychological tools can include different types of signs, words in a text, formulae, charts, diagrams, maps etc (Kozulin 1998).[28] However, McDonald, Le, Higgins and Podmore (2005) note that it is difficult to find studies with a specific focus on a particular artefact, its history, and influence on human functioning, since artefacts are generally referred to, rather than described or studied. What McDonald et. al. (2005) refer to as artefacts is, in this dissertation, referred to as technical and psychological tools.

I have selected this theory because I view the users' process of going from a situation where they cannot accomplish a work task goal in the technical tool, to a situation where they can as a process of learning and development. These theoretical concepts provide knowledge that allow us to understand how a technical communicator can scaffold a user towards shaping thought they cannot shape based on their existing knowledge. This is motivated since the analysis of the current

[28] Psychological tools can also be notebooks, clocks, etc, which relieve cognition (Säljö, 2013). The design of psychological tools in a culture, mirror humans' thinking in the culture.

situation shows evidence that the goals and task plans the users shaped did not correspond to the ones required to accomplish the goal in the technical tool.

Drawing upon on Cole, John-Steiner, Scribner and Souberman (1978), throughout an individual's activity thought influences action and the result of one's action influences thought. When psychological tools enter in between the individual's thought, action and the object of the activity, they mediate thought and action (Friedrich 2017). That is, the result of the action of using psychological tools gives rise to the shaping of new thoughts and inner speech, which influence the planning of the following actions. [29] Following Cole, John-Steiner, Scribner and Souberman (1978), Wertsch (1985), Cole (1999), and Kozulin (1998, 1999, 2003), a number of circumstances must be considered for psychological tools to function as mediating agents that support users in the shaping of a thought and inner speech regarding the results that are possible to accomplish. Psychological tools can only function as a mediator if the user learns what the psychological tools signify. To mediate thought and task actions when the technical tool is used in work tasks, the user must either have internalised the psychological tools, or have them available externally and use them during task execution. Furthermore, the user must be motivated to both engage in the activity to learn the psychological tools and use them in the task with the technical tool. The technical communicator who scaffolds the user must take the user's actual and potential cognitive development level into account when designing the psychological tools and when designing the scaffold. When designing psychological tools, the technical communicator should take into account the activity system in which the technical tool is used. The aspects of these theoretical concepts that are used to inform the work of suggesting a design method for technical communicators are described below.

A psychological tool signifies a phenomenon which can be something in the world, for example, a component in a technical tool. Drawing upon Bonk and Kim (1998), in order to learn what a psychological tool signifies, learning takes place in a mediation activity. In such an activity the technical communicator is the knowledgeable other who collaborate and scaffold the learner. For example, when the technical communicator points to a phenomenon in the world and uses external

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[29] Vygotsky was the first to attempt to relate Marx's theory of society (known as historical materialism) to concrete psychological questions (Cole, John-Steiner, Scribner & Souberman 1978). According to Marx, the historical changes in society related to the use of technological devices, transforms the consciousness and behaviour of those who use it and the society. Vygotsky also drew upon Engels' concept of human labour and tool use as the means by which man changes nature and, in so doing, transforms himself.

speech to explain what it is, the user is supported to shape a thought about it (thereby, intersubjectivity is established). For such learning to happen, the learner must perform a task within the mediating activity (Kozulin 2003), in which the knowledgeable other supports their self-regulation process towards accomplishing a learning goal.[30] Once the user has learned what a set of psychological tools signify, the learning goal can be to arrange them in a certain order, and the new arrangement will mean something new and mediate thought.[31] According to Gallimore and Tharp (1990) learner have "bits of information to construct meaning and the teacher assists by providing the structure and the questions that provoked the assembly of those information into organization and meaning" (p.177). By drawing upon Tharp and Gallimore (1991), Stone (1993) and Bonk and Kim (1993), relevant scaffold techniques, in this case, are instructing, questioning, feedback and cognitive structuring. The technical communicator can also start the mediating activity and ask the user to complete it (drawing upon Säljö 2013).

Psychological tools mediate the execution of action steps if the user has either internalised the psychological tools, or read them during the execution of action steps with the technical tool. The psychological tools then mediate users' thought and actions in the technical tool. This is because when the user shapes a thought corresponding to the phenomenon, they have learned what the psychological tool signifies in the mediation activity.[32] The shaped thought influences the shaping of a goal and task plan which, in turn, influence what action steps are executed. This means that the technical communicator must encourage the user to read the psychological tools during task execution. The psychological tools also relieve working memory, since the user does not have to store the components and results related to what they are doing in working memory.

Technical communicator ought to also take intentionality into account. The user must be motivated to both learn the psychological tools in a learning activity,

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[30] Memory studies on subject performed tasks have shown that verbal phrases are better memorised which enhances recall when participants perform actions as they learn verbal phrases (Engelkamp & Cohen 1991). Following this, it is likely that individuals performing the mediation activity will remember better compared to those who only read the scaffold instruction.

[31] Karpov (1995) developed psychological tools to aid the comprehension, recall and construction of a story. The instructor read a story and asked readers to use psychological tools to signify central themes in the story. When the readers then rearranged the tools, they constructed new stories.

[32] Vygotsky, Luria and Leontev studied how psychological tools break up the interaction between the individual's thought and the object of activity in several studies. See, for example, Cole, John-Steiner, Scribner and Souberman (1978).

and be motivated to read about them while executing action steps in the technical tool in order for the mediation of thought and action to take place.

The concept of actual and potential cognitive development level is essential when suggesting an approach for technical communicators. Each individual is unique in that their mental functions (such as knowledge) at a given time are on a certain level, which has developed through intrapsychological processes. Their mental functions have developed in a certain sociocultural environment, thus what they have learned depends on the environments in which they have acted. According to Cole, John-Steiner, Scribner and Souberman (1978), this is referred to as the individual's actual development level. The actual development level can be assessed from the work task goals an individual can accomplish independently. Each individual also has a potential level, which relates to the cognitive functions that have not yet developed but are in the process of being developed if they collaborate and learn with the support of a mediating agent. The potential level can be determined by assessing what work task goals they can accomplish when supported by a mediating agent. Within Vygotsky's sociocultural theory, an individual's distance between the actual level and potential level is referred to as the zone of proximal development (Cole, John-Steiner, Scribner & Souberman 1978). Two individuals on the same actual level, may have different potential levels. Consequently, to accomplish a certain work task goal (which equals individual's potential level) two individuals may have to start from two different actual levels. In either case, when they collaborate and learn, they both develop mental functions so that their potential level becomes their new actual level and they have appropriated the knowledge they need to be in a position to learn other tasks. According to Cole, John-Steiner, Scribner and Souberman (1978), "what the individual can do with assistance today, they can do by themselves tomorrow" (p.79). Furthermore, an individual's cognitive development happens faster when collaborating than when exploring alone (Tharp & Gallimore 1991). From the viewpoint that a certain task to be learned in a technical tool equals each user's potential level, the actual level among the users will likely differ. Nevertheless, a technical communicator designing technical information during product development cannot know and depart from each users' actual level. The technical communicator must assume that the user has some level of knowledge, thus also a certain actual level from which the mediating activity can be based. This means that the technical communicator needs to define what actual level the user is expected to have. When defining the

actual level, the technical communicator needs to identify what skills they have and do not have, which depends on their sociocultural environment.

When designing psychological tools to mediate thought on goals and task plans, it is suggested that the technical communicator takes users' activity system into account. Technical tools are used as an aid to accomplish work tasks in a specific activity system, such as a repair workshop where maintenance technicians perform machine maintenance. In line with Cole (1998), activity systems are viewed as cultural communities of practice, which are shaped by the individuals who have acted within them throughout their history. The rules governing how technical tools are used, meaning what actions and results usually take place, are shaped by the individuals in the system. This is because technical tools have both a material aspect and a cultural dependent meaning aspect, and they mirror the activity system in which they are used. Cole (1998) refers to the meaning aspect as the tool's ideal aspect by drawing upon Hegel and Dewey.[33] It is the tool's activity system-specific meaning aspect that must be learned to be able to use it in the system. Thus, the technical communicator should be aware of what results typically take place in the activity system when designing psychological tools.

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[33] Henceforth, the meaning given to a technical tool depends on the activity system in which it is used. The same technical tool can be given a different meaning in another activity system.

6 | DISCUSSION

This chapter discusses how the results and the suggested design method advance existing knowledge in the technical communication field, and what implications the suggested design method has for the design practice of technical communicators. The discussion highlights the contributions as well as the limitations of this dissertation. First, a summary is given which focuses on the results, the analysis and the suggested design method.

This dissertation deals with the use and design of technical information, based on over 90 hours of observations of process operators and maintenance technicians' work task and information-seeking behaviour. The research aims to contribute knowledge to technical communicators about how technical information can be designed to support industrial professionals in accomplishing their work tasks. The objective is to suggest a design method on how technical information can be designed to increase process operators and maintenance technicians' chances of accomplishing a work task using tools in industrial settings.

Studies have been conducted on process operators and maintenance technicians' behaviour when searching and reading technical information to use technical tools at work to perform a work task. The empirical material has been analysed using Vygotsky's sociocultural theory—which has been used very sparingly in technical communication so far. This was to gain a deeper understanding of how thought and language influence—and are influenced by—searching and reading behaviours, as well as the task behaviours in a tool. Based on the analysis, the implications for the design of technical information by technical communicators are elaborated and a design method is suggested which can help technical communicators support process operators and maintenance technicians in shaping goals and task plans, and carrying out the correct sequence of action steps.

The empirical results show that the participants shifted between searching and reading and executing action steps in a technical tool several times in order to

accomplish a work task. On several occasions, they could not accomplish the work task. At times, they executed a sequence of action steps in the technical tool, before and after shifting to technical information, which did not correspond to a sequence that would have led to the accomplishment of the work task. When consulting the technical information after such a sequence, they searched and read pages that were both relevant and irrelevant (according to the researchers who were tool experts) to accomplish the work task. At times, reading pages that the researcher had defined as relevant did not support the participant to self-regulate towards executing the correct sequence of action steps. Even more obvious was that reading pages that were not relevant also failed to support the participants in executing the correct sequence of action steps.

The analysis illuminates that work task goals and action steps in a task plan equal results in the technical tool which the user desires to accomplish. If the user lacks relevant knowledge of what results are possible in a technical tool, they may shape work task goals that are not possible to accomplish. Or, they may shape task plans that will not lead to the accomplishment of their goal. The first implication is that technical communicators ought to provide support to users in order to enable them to shape a thought about what results are possible to accomplish when using a given technical tool. The second implication is that this support should not be embedded within technical information where the user must search and read in order to find it (which is discussed below).

Drawing upon Vygotsky's theoretical concepts of mediation of thought through the presence of a mediating agent, I suggest that technical communicators design psychological tools and scaffold the user as they use those tools to build a result model.

Before discussing the results and the suggested design method regarding how they advance existing knowledge and what implications they have on technical communicators' design practice, the limitations of this dissertation must be noted. The empirical material is limited to 12 participants in a Swedish context. The empirical material contributes to understanding the searching and reading behaviour of process operators and maintenance technicians, although the behaviours of the participants in the first study were studied in a controlled laboratory environment and they did not work or have training as process operators. One aspect that can potentially weaken the analysis is that Vygotsky's sociocultural theory this dissertation is using was mainly developed from studies on children. However, recently scholars in the andragogic field have studied and discussed the development of

higher mental functions among adults (see, for example, Bonk & Kim 1993). Tharp and Gallimore (1990), state that learning and development of higher mental functions as depicted in Vygotsky's sociocultural theory continue throughout life, as appropriation. Another possible limitation is the researcher's background, beliefs and knowledge as a middle-aged white male living in western culture, which can influence the analysis when it comes to the researcher's awareness of certain aspects. A limitation that could weaken the trustworthiness of the results is that little attention was paid to differences in the participants' backgrounds, in terms of their sociocultural history, reading abilities and deficits. Although the design of the technical information the respondents used in the laboratory study was based on the researcher's 25 plus years of experience in the technical communication field, the design of the technical information may have influenced the participants' behaviour nonetheless. A different information design, perhaps one more in line with the guidelines suggested in minimalism, or using another modality, may have given rise to different behaviours. The number of design iterations to realise the intended support were limited. Moreover, there is a possibility that the attempt to generalise the design method based on the empirical material within a broader context of technical tools weakens the validity of the suggestion in terms of it being too separated from the particular experience.

IMPLICATIONS ON CURRENT KNOWLEDGE

Previous research on user behaviour shows that novice users learning a new software were not interested in reading about it to learn prior to engaging with tasks in the software. Instead, they wanted to jump directly into the software to learn it by discovering how it works by exploring and testing different strategies (Carroll 1990). According to Carroll and Rosson (1986) users assimilate what they see into what they already know to make sense of something (referred to as the assimilation paradox). This research, which is based on Piaget's theory of cognitive development, has shown that novice users become overwhelmed and confused at the beginning of a task they are attempting independently. Through explorative learning behaviour, however, they eventually make sense of the task. An explorative learning behaviour is in line with the task behaviour Norman (2013) states users have when carrying out everyday tasks. He points out that users form explanations about what they experience, which are naïve. There is a gulf between what they

believe they should do and the state of the world as they interpret it. They have to map out the relationship between what they see and their intentions—both before an action is carried out and after it has been completed.

The behaviour of almost all the participants in the laboratory study (see paper A) can be described as explorative learning behaviour following the learning behaviours of the novice users in Carroll's (1990) studies. When the participants in the laboratory study started to work with the liquorice machine, they tried different task strategies which sometimes resulted in sequences of action steps which did not correspond with the actual sequence required for accomplishing the work task. Since the liquorice machine was new for them, they tried to make sense of it by activating prior knowledge about similar tools they had used. Nevertheless, the maintenance technicians in the second study where not observed to explore or test to the same extent as the participants in the laboratory study. The maintenance technicians had an average of six years of experience working on the machines they maintained (see paper E). These observations tentatively indicate that the explorative learning behaviour decreases as knowledge about the technical tools and object of activity increases. However, no such conclusions can be drawn from the empirical material since the two studies were not controlled so that the participants prior knowledge was the only independent variable, influencing their learning behaviour (dependent variable).

The participants in the laboratory study performed several different information-seeking tasks to accomplish a single work task. They looked up several pages within one information-seeking task, and they searched and read pages that were not relevant to the work task. They looked up the same page several times throughout the process of completing a work task, and they could not execute the correct sequence after having read relevant pages. Searching and reading were not as straightforward as the process of looking up a relevant page, reading it and then self-regulating the actions steps towards accomplishing the work task. There is no reason to believe that these behaviours are entirely unique to the few participants in the laboratory study or the information design they used. How often this happens must be further studied and discussed.

One possible interpretation of these behaviours is that the participants were exploring and discovering the technical information in parallel with exploring and discovering the technical tool. They would look up a page and read it, return to executing action steps in the technical tool, experience difficulty progressing in the

work task, and then the process would start over as they searched again and then returned to execute a different sequence of action steps.

It was analysed that participants had found information they deemed relevant in each information-seeking task, since they stopped searching and reading and returned to the technical tool. Thus, it seemed like they did not experience major difficulty learning on their own by exploring both the technical tool and the technical information. However, in a professional setting, such as in safety-critical industrial environments, exploring a technical tool in order to learn it does not seem appropriate considering the potentially severe consequences an incorrect sequence of action steps might have—such as damage or injuries. Furthermore, it is time-consuming and if the user does not progress in their explorative learning, they might grow frustrated and abandon the work task altogether. The user will not progress if they are frequently unable to shape a mental model of what they read. Nor will they progress if the mental model they shape turns out to be incorrect when the sequence of action steps does not lead to the accomplishment of the goal. Or if they evaluate that the accomplished result does not equal the work task goal. This happens when users read pages that are not relevant to what they are doing or when they read a page that is relevant but reject, ignore or re-interpret parts of it. Such circumstances could explain why some users prefer not to use technical information in which they have to search and read. Previous research in technical communication has reported that users find such technical information difficult to use. Users say they cannot find what they need or understand what they find (Martin, Ivory, Megraw & Slabosky 2005; Novic & Ward 2006a; Novic & Ward 2006b; Wieringa, Moore & Barnes 1998). However, this previous research is mainly based on interviews and questionnaires. Since individuals may be unaware of many tasks and actions they perform (Bedny, Seglin & Meister 2000), users might be more likely to report what they think happened rather than what actually happened (Eager & Oppenheim 1996). How frequently users struggle when using technical information and how big the consequences are needs to be further studied.

This dissertation advances current understanding in the technical communication field with the insight that a user's knowledge of a technical tool—and what results can be accomplished—influences whether they can be supported in accomplishing a work task through searching and reading technical information. If a user has little knowledge on what results can be accomplished or if they have misconceptions, meaning their knowledge does not correspond with the technical tool,

the risk increases that they will search and read non-relevant pages and misunderstand the relevant pages. This could lead to the user giving up. The chicken or the egg problem presents itself here, if the user needs to possess prior knowledge about a technical tool prior to searching and reading in order to decrease the risk of searching and reading non-relevant pages or misunderstanding the relevant ones. In this case, an information design solution that depends on the user independently searching for and reading relevant information in order to learn new knowledge is counterintuitive.

This relates to research on reading comprehension, which has found that the reader needs to have knowledge about the domain the text is about in order to comprehend and recall what is read (Caillies, Denhière & Kintsch 2002; Cain, Oakhill, Barnes & Bryant 2001; Elbro & Buch-Iversen 2013; Garnham & Oakhill 1996; Johnson-Laird 1983; Kintsch 1988; McNamara, Miller & Bransford 1991; McNamara & Kintsch 1996; McNamara, Kintsch, Songer & Kintsch 1996; Rawson & Kintsch 2004). Readability (Begeny & Greene 2014) and text coherence (McNamara & Kintsch 1996; McNamara, Kintsch, Songer & Kintsch 1996) have an influence whether a reader can understand, but the major factor for comprehension seems to be prior knowledge. Such a viewpoint provides input for research studying the effect of declarative information on users' task performance. Some studies show that reading principles do not have an effect on users' task performance (Eiriksdottir 2011). One possible interpretation is that these users did not have the prior domain knowledge needed to shape a valid mental model of what they read or to engage in conceptual change.

The suggested design method in this dissertation aligns with previous research indicating that the purpose of technical information is to support the user in shaping mental models of the technical tool that aid task execution. Previous research has acknowledged that users search and read technical information. However, little previous research could be found that takes users' searching and reading behaviours into account when suggesting how technical information can be designed. The design principles in previous research, in large part, do not discuss how to design in order to support end-users in finding the relevant information for the task they are performing, or how to mitigate misunderstandings. One stream of research assumes that the user can shape valid representation from reading technical information that consists of both procedural and declarative information.[34]

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[34] See Bibby and Payne 1993; Bibby and Payne 1996; Borgman 1999; Catrambone 1995; Eiriksdottir 2011; Karreman and Steehouder 2003; Karreman and Steehouder 2004; Kieras and Bovair

Declarative information are either kept as texts separate from the instructions or embedded within instruction steps. Information about how a tool works is the most common type of declarative information (Eiriksdottir 2011), which is called, for example, principles (Eiriksdottir 2011; Catrambone 1995) functional information (Smith & Goodman 1984) or system information (Karreman & Steehouder 2004). By reading declarative information, the user is assumed to shape a more comprehensive mental model of, for example, how the system works, compared to when only reading procedural instructions. Having a better understanding of the system is expected to lead to better learning when using the system, specifically when it comes to transferability and problem solving (Eiriksdottir & Catrambone 2011). Nevertheless, no research on procedural and declarative information could be found suggesting how to support the user in finding the information that is relevant for the task at hand, for example in a manual containing large amount of information.

Another stream of research (see Carroll 1990; Carroll 1998; van der Meij & Carroll 1998) suggests that the design ought to encourage the user to shape a mental model by exploring and discovering the technical tool, not from reading. This design suggests minimising the obtrusiveness of support learning (Carroll 1990). van der Meij and Carroll (1998) report that users commit semantic errors which indicates misconceptions about the technical tool they are using. Such misconceptions introduce the risk that users search and read pages that are not relevant to what they are doing, and ignore or re-interpret the relevant pages. This research has not thoroughly studied users' searching and reading behaviours in a minimalistic design or how to design to mitigate the risk of users reading non-relevant information or misunderstanding relevant information.

A departure for the design method in this dissertation is that support for shaping a mental model on the results which can be accomplished cannot be embedded somewhere in a manual where the user must find it. The suggestion is that the user learns and develops knowledge on the results through building a result model by arranging psychological tools signifying results and components. This design is delimited to supporting the shaping of a mental model about the expected results. When the user has internalised knowledge on the results, they are assumed to be able to shape valid goals and task plans. However, a user may still need information while executing action steps, for example, information on what a psychological

1984; Konoske and Ellis 1991; Kontogiannis and Sheperd 1999; Morris and Rouse 1985; Payne, Howes and Hill 1992; Reder, Charney and Morgan 1986; Smith and Goodman 1984.

tool in a graphical user interface signifies, how much a product weighs or where a menu command is located in an interface. In this case, the technical communicator needs to design information that addresses users' information needs. In the suggested design method, this type of information can be designed in step four.

This dissertation has investigated what types of information needs process operators and maintenance technicians show evidence of and discussed the possibility for a technical communicator to design information in order to satisfy them (see papers C, D, E and F). This dissertation has also highlighted that designing to satisfy the types of information needs end-users show evidence of, is challenging. This is for several reasons. Firstly, it is challenging for a technical communicator designing technical information during product development to identify the types of information needs end-users will later exhibit. This is because there are no users that need information in advance, while the product is still being developed and has not yet launched. Secondly, observing end-users' behaviours and analysing what information needs these behaviours show evidence of is time-consuming. Thirdly, information needs may relate to and depend upon an observed individual work task context (see paper C). Fourthly, depending on a user's knowledge, they may show evidence of information needs that are not relevant from a viewpoint of the technical tool. Users may have misconceptions or not know what they need. Paper F discusses these challenges in greater depth. If the technical communicator decides to analyse the information needs users show evidence, and deal with the aforementioned challenges (which is not the scope of this dissertation), they need to decide how to organise the designed information into technical information.[35] An initial idea is to organise the technical information in a manual or handbook so that the chapters, sections and subsections are structured according to the results that can be accomplished using the technical tool. Another tentative idea, in order to satisfy information needs, is to make information available from the psychological tools signifying components and results (related to how a component works, where it is located, and what the result looks like). In this case, the mediat-

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[35] Standards, such as IEC/IEEE 82079-1:2019 Preparation of information for use (instructions for use) of products (IEC 2019) and the DITA Darwin Information Typing Architecture (OASIS 2015), recommend that technical information contain procedural and declarative information. There seems to be a lack of knowledge about how task instructions, concepts and reference information could be identified when designing technical information as well as what purpose conceptual or reference information could serve. The DITA standard says that conceptual information conveys an idea.

ing activity of building the result model not only supports the learning and development of the results which are possible to accomplish, but also supports the learning of what information exists and how it is organised. When building a result model of the psychological tools, the user also effectively structures the technical information.[36] As the user builds the result model, they learn how the technical information is structured and what the individual parts signify.[37]

IMPLICATIONS FOR TECHNICAL COMMUNICATORS' DESIGN PRACTICE

Previous literature in technical communication discusses that a technical communicator needs to be knowledgeable about their target groups, their target groups' work tasks, the technical tool as well as the environment in which the tool is used. In my experience working as a technical communicator for industrial equipment for over 25 years, I've noticed that within the field of technical communication it is often discussed how much knowledge a technical communicator needs to possess about the technical tool. This dissertation contributes to this discussion with the insight that, in order to design psychological tools, the technical communicator needs to possess knowledge about what results are possible to accomplish with a technical tool and which components generate such results. Furthermore, the technical communicator needs to be knowledgeable about how to scaffold users in their process of learning and development, and thus become the voice of the knowledgeable other.

When technical communicators design technical information during product development, the technical communicator and the user are not physically located in the same place, such as a repair workshop, where they can collaborate. Users often consult technical information in situations where they are alone, or at least

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[36] Another aspect of the design to build a result model, is that the user can explore and discover the psychological tools and does not have to try and test the tool, to learn. This can be an advantage in industrial safety-critical environments, for example.

[37] The built model presents visually all the information available. This is different from contemporary technical information, where the user is limited to visually reading one page at a time. After skim-reading several pages and deciding on which page to read in depth, they have to keep the previous read pages in working memory. In a situation where the user has built the result model and later has an information need to know how to accomplish a certain action step, they can locate the relevant psychological tool in the landscape of built model, and thus not have to search in the same way as in contemporary text- and image-based technical information.

without the physical presence of the technical communicator. To apply Vygotsky's sociocultural theory when designing information for such situations might seem counterintuitive, as this theoretical perspective emphasises that learning and development of higher mental functions happens in a social setting. However, this dissertation puts forward the view that the technical communicator can scaffold the user, since the voice of the technical communicator is present throughout the designed information (which is also highlighted by Säljö 2013). Thus, the technical communicator needs to take on the perspective that the purpose of their design is to scaffold the user towards learning and development. Here, technologies such as social media, and chatbots allow for scaffolding techniques, such as instructing, questioning, feedback and cognitive structuring.

A consequence of taking a sociocultural perspective when designing technical information is that the technical communicator needs to assess the target end-users' sociocultural backgrounds into account early on in the design process. If the individuals that make up the target audience are spread across the globe, there are cultural differences regarding how individuals learn, individual differences related to reading and searching skills, as well as disabilities. For example, in most pre-technological cultures, individuals learn through modelling rather than through instruction (Scribner & Cole 1973). In such cultures, using psychological tools to mediate thought will not work. One way for a technical communicator to understand cultural differences among their target audience is to first identify the different activity systems in which users will interact with the technical tool, and then analyse the cultural habits of each activity system.[38] By understanding which activity systems the technical tool will be used within, the technical communicator can determine whether designing psychological tools is appropriate for learning. Furthermore, the technical communicator can assess the user's actual development level within a system. If all users in an activity system do not reach an assumed

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[38] An activity system (or activity setting) is the task activity and the setting in which work tasks are performed (Tharp & Gallimore 1991). Each activity system is unique in that the knowledge generated, as well as the task behaviours and how a technical tool is used, depend on the system and the individuals who have participated in it throughout its sociocultural history. For example, how a process software is to be implemented, in terms of how parameters will be configured, which functions will be enabled or disabled, depend on the activity system. Knowledge that's been developed on how to perform tasks in a system is not directly transferable and does not guarantee that the individual can perform similar tasks in another similar system (such as the process control room in another company, for example). Furthermore, it's not only the tasks that depend on an activity system but also, the technical tools which are shaped by the activity system and can be viewed as materialised forms of thinking (Säljö 2013).

actual development level, then designing psychological tools might not be suitable. One challenge is that a technical tool can be used in future situations the technical communicator is not aware of at the time of designing technical information. In this case, the technical communicator could be explicit on what activity systems and development level the technical information is designed for.

As the results in this dissertation show, users search and read when they need information due to not being able to progress in a work task. Since the suggested design method does not aim to satisfy an information need, it can be discussed whether the user should be engaged in building the result model before starting to work with the technical tool, or only when they reach out for support. If the user can spend time learning and developing knowledge while performing a work task, they can be motivated to engage in building the result model at an early stage of their tool usage. Thus, instead of learning by exploring the technical tool (which may not be possible in some industrial settings), users learn by exploring the psychological tools. If the work task is time-constrained and the user must be trained prior to performing the work task, they can be engaged in building the result model as part of self-directed workplace training, where they step aside from work tasks. The design can also be used to refresh and recall knowledge, for example in the morning before leaving for work at an industrial worksite.

Since active users are interested in throughput (Carroll & Rosson 1986), most want to explore the technical tool before engaging in a learning activity. Thus, the technical communicator is faced with a challenge to motivate the user to engage in learning and knowledge development prior to performing tasks with the technical tool.[39] One advantage to engaging the user in building the result model early on, is that the risk of them shaping an erroneous mental model from exploring, may lead them astray, is mitigated. If the user first tries to learn by exploring and then comes to the mediating activity having shaped an invalid mental model, it may cause them to ignore, reject or reinterpret parts of the scaffold instruction.

A user who has learned what results can be accomplished from other sources of information, and has a need to know certain detail such as the weight of a component, may not be motivated to build the result model. This is because the effort involved in satisfying the need becomes greater than the intensity of the information need.

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[39] Integrating gamification features might increase the user's motivation to engage in accomplishing the learning goal related to building the result model.

7 CONCLUSION AND FUTURE RESEARCH

The research in this dissertation aims to contribute knowledge to technical communicators about how technical information can be designed to support industrial professionals in accomplishing their work tasks. To contribute to how technical information can be designed, I conclude that:

1. Technical information ought to support the user in shaping thoughts of what results that can be accomplished with the technical tool, and
2. For novice users, this support ought not to be embedded in technical information, forcing them to search to find it.

The first conclusion is drawn from the analysis of the empirical results, which illuminates that the actions the participants execute are based on what goals and task plans they shape prior to executing them. Their goals and task plans are shaped by recalling knowledge on what future desired states of the technical tool, hence results, are possible to accomplish. From this, I make the first conclusion that technical information ought to support the user in shaping thought on what tool results are possible. From such support, the user can shape valid goals and task plans, which support the execution of action steps towards the accomplishment of a goal.

The second conclusion draws upon the empirical material, which shows that the participants show evidence of many different types of information needs throughout the process of performing their work tasks, each one specific to a certain task situation. Technical information, such as a user manual, contains many different types of information, where only some is relevant to the user in a certain task situation.

The participants in the first study not only explored the technical tool to learn it—they tried something, experienced that it did not work, self-regulated and then tried doing something differently, in line with previous research on user behaviour. Their behaviour while searching and reading can be depicted as exploring the technical information as a means of learning it. They searched and read something they found, and if it seemed relevant, they returned to the tool and tried it. They shifted back and forth between interacting with the tool and searching and reading. A process in which they, for example, read the same pages several times until they had either accomplished something or given up. As a result of such explorative learning behaviour, the pages a user searches and reads in technical information are either relevant to the task at hand or not (this is from the tool expert's perspective). However, novice users have a slim chance of independently verifying if a page they have searched and believe to be relevant to the task at hand is relevant or not (as judged by the tool expert). Obtaining new knowledge by reading a page that is not in fact relevant—but is according to the user—may lead to an execution of actions that do not lead to the accomplishment of the goal. It is only when users execute actions and evaluate the outcome of the task, that they can assess whether the pages they have read are relevant or not.

The analysis highlights that the reason why novice users explore technical information and may end up reading irrelevant pages is due to a lack of tool knowledge. The participants in the first study were novices, as they used a tool they had not encountered before. A lack of knowledge about what results are possible, or on whether the results are possible or not, means that novice users either cannot shape goals or task plans—or the ones they do shape are not possible to accomplish. Such circumstance may lead to users searching and reading a page that is not relevant to the task at hand (however, it may be relevant to the non-relevant goal). If we turn this the other way around, it means that to search and read pages that are relevant, the user needs to possess knowledge about the tool. Such a claim is supported by the empirical material which highlights that maintenance technicians, who collectively had an average of six years of working experience, did not explore the source of information they used. I claim this was due to that, thanks to their prior experience, they possessed knowledge on what results were possible in their tools and knew these results were actually possible to accomplish. The claim that a user's knowledge level about the tools they are using is one factor influencing whether or not they explore it is also warranted from the viewpoint that technical information functions as a mirror of the tool. Meaning that the way

a tool is designed, it's software and hardware, has a direct influence on how the information is designed in terms of what information is included and how it is organised. So, having knowledge about the tool means having knowledge about the technical information.

Based on the above reasoning and the first conclusion, I make a second conclusion that, for the novice user, support for shaping thoughts on the results that can be accomplished with a tool, ought not to be embedded in technical information, forcing the user to search to find it.

This dissertation suggests a design method, based on Vygotsky's sociocultural theoretical concept of mediation of psychological tools in task activities. The suggestion is that technical information becomes the voice of the knowledgeable other who scaffolds the user towards learning and development. As the user uses their hands to move tangible tokens to build a result model, their thought is shaped through action.

FUTURE RESEARCH

This dissertation contributes knowledge on the design of psychological tools, but there is much more left to do. One possible direction is to study how different designs of psychological tools shape thought through action and relate them to other studies on how action shape thought (see for example Jamalian, Giardino & Tversky 2013; Kirsh & Maglio 1994). Another possible direction is to study how technical communicators can scaffold and collaborate with users through the designed technical information. Since there are different scaffolding techniques, more knowledge is needed on the effect of different techniques. Such investigations further advance our knowledge on how Vygotsky's sociocultural theory can inform the design of technical information and what benefits and drawbacks it contributes. This relates to the value of design; innovation value is realised when the user is able to accomplish a work task goal at a satisfying level of efficiency.

Future research could investigate other modalities besides designed information based on text and/or images, regarding how a technical communicator can scaffold users by being present as a mediating agent through psychological tools. This is since technical communicators design during product development and cannot support users in real-time. A reflection is that modalities such as live-action

videos (see Eriksson 2018), digital games built on gamification, embedding collaboration within a technical tool interface, collaborating in real-time through the design technical information or social media, and chatbots driven by artificial intelligence could be fruitful to investigate. The difference in effect regarding whether psychological tools are realised as tangible tokens or are realised as digital tokens in a virtual or augmented reality environment could be another possible direction for future research. The technical communicator must not be the one scaffolding. Instead, the technical communicator could design support for other users, enabling collaboration between users, where one user scaffolds another. When studying different modalities, it is also relevant to study how collaboration and task performance progress as the user uses other sources of information besides the psychological tools. In such studies, the research of Spinuzzi and Zachry (2000) relating to ecological genres should be considered.

The suggested design method in this dissertation focuses on how to support users in the shaping of thoughts about the results that are possible to accomplish with a tool. As this dissertation has shown, maintenance technicians show evidence of many different types of information needs which are not addressed by the suggested design of psychological tools. A user who consults the manual to address a specific need must be supported in some way. Future studies could investigate if such needs can be addressed through the design of tokens signifying results and components. It could be advantageous for users' information needs to be addressed through psychological tools as such tokens—since the user builds the result model, they know how the manual is structured. But if this means that the complexity of building a result model increases as the number of tokens grow, similar to the discussion about fading and specificity for instructions (Eiriksdottir & Catrambone 2011), this needs to be catered for when designing tokens for action. Another path is to design technical information in which content is organised according to, for example, the results that are possible to accomplish.

In relation to what is noted above, future studies are needed concerning how technical communicators can predict information needs when they are designing technical information during product development. Future research could investigate what types of information needs users have at certain level of development and how the information needs change as the user develops task abilities. In other words, what questions are asked in the early levels compared to later levels of development. One way to study such information needs is to consider user-generated content. For example, on-line forums where professionals collaborate by

asking and answering questions, could be used as empirical data. Also, companies' support databases could be analysed. Such databases contain the answers given to questions by a support engineer when collaborating in real-time with users (in this context, the support engineer is reacting to information needs instead of predicting them).

A future area of research that has been opened by this dissertation is the factors that influence searching and reading behaviour. This dissertation has identified the user's knowledge level of what results are possible to accomplish as one factor influencing this behaviour. Future research could investigate if and how different information designs influence the behaviour. This could relate to both the micro-level, how sentences are organised to create a text, and the macro-level, how different texts are organised into an information architecture. Within such studies, a discussion should be put forward regarding what a text is within technical communication.

The work in this dissertation awakens questions on how to ensure that the sequence of steps a user follows actually makes it possible to execute a task with a tool. A technical tool constantly changes its state; either when the user changes a parameter or when the tool changes its state due to an external input. When the technical communicator designs an instruction, they assume the tool is in a certain state. But if the tool state implied by the instruction, which the user successfully reads, differs from the actual tool state, the user may get stuck when executing the task plan. Future research is needed to investigate how instructions can be designed to be more dynamic, so that whatever instruction is presented to the user reflects the current tool state.

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