From Free-form to Structured Design Notes: A Study of Electronic Engineering Notebooks

by

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A thesis submitted in conformity with the requirements
for the degree of Master of Applied Science,
Graduate Department of Mechanical and Industrial Engineering,
University of Toronto

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Abstract

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This thesis addresses the problem of non-intrusive capturing engineer's notes into an information system and structuring them to facilitate subsequent information access.

An Electronic Engineering Notebook was designed and implemented. The EEN supports free-form interaction, and allows for semantic information structuring using terminology based on engineering ontologies. The EEN employs context sensitive labelling and linking in context.

An experiment was conducted in which free-form and form-based note-taking interfaces were compared with respect to capturing and structuring notes from a design meeting. Furthermore, suitability of domain-based and user-defined terminologies for semantic structuring was tested.

Results from the experiment confirmed that a free-form interface was easier to use for note-taking than were forms with fixed structure. Furthermore, based on these results, an important distinction needs to be made between structuring mechanism and semantic categorizations required by structuring. While the structuring mechanism is a function of the user interface, the terminology used for categorization is independent of the user interface. Delaying structuring in the free-form interface made that interface easier to use than forms. However, difficulties with applying semantic categorizations were observed in both types of interfaces. Furthermore, the results indicate that terminology should be chosen appropriately to a task, and that experienced users have less problems with applying it. The experiment also demonstrated high diversity in note-taking styles, thus highlighting the need to accommodate individual preferences in electronic notebooks.

Od wolnoformatowych do zestrukturyzowanych notatek inzynierskich: Studium elektronicznych notatników inzynierskich.

Streszczenie (Abstract in Polish):

Przedmiotem tej pracy sa elektroniczne notatniki umozliwiajace naturalne zapisywanie inzynierskich notatek, a nastepnie ich strukturyzacje ulatwiajaca pózniejszy dostep do informacji zawartej w tych notatkach.

Zaprojektowano elektroniczny notatnik inzynierski (EEN), który charakteryzuje sie wolnoformatowa interakcja z uzytkownikiem i pozwala na semantyczna strukturyzacje notatek przy uzyciu terminologii opartej na reprezentacji wiedzy inzynierskiej.

W przeprowadzonym studium porównano wolnoformatowy interfejs z opartym na formularzach interfejsem z ustalona z góry struktura, pod wzgledem zapisywania i strukturyzowania notatek wykonanych podczas zebrania projektowego. Zbadano takze odpowiedniosc terminologii opartej na inzynierskich ontologiach oraz terminologii zdefiniowanej przez uzytkowników do semantycznej strukturyzacji.

Wyniki studium potwierdzily, ze wolnoformatowy interfejs jest latwiejszy w uzyciu przy pisaniu notatek, niz interfejs z ustalona z góry struktura. Studium wskazalo na koniecznosc rozróznienia pomiedzy samym mechanizmem strukturyzacji, a semantyczna klasyfikacja dokonywana przy strukturyzacji. Podczas gdy mechanizm strukturyzacji zalezy od interfejsu, terminologia uzyta do klasyfikacji jest od niego niezalezna. Opóznienie strukturyzacji w wolnoformatowym interfejsie ulatwilo jego uzywanie, jendakze trudnosci w stosowaniu semantycznej klasyfikacji zostaly zaobserwowane w obu typach interfejsów. Wyniki wskazuja na waznosc wyboru terminologii odpowiedniej do doswiadczenia uzytkowników i do typu notatek, które sa zapisywane. Doswiadczeni uzytkownicy mieli mniej problemów zarówno ze stosowaniem terminologii, jak i z semantyczna klasyfikacja. Studium pokazalo takze duza róznorodnosc stylów robienia notatek, wskazujac tym samym na potrzebe uwzglednienia w elektronicznych notatnikach indywidualnych preferencji uzytkowników.

Acknowledgments

I would like to express my deep gratitude to my supervisor, Professor Mark S. Fox, for his guidance, support, and valuable time. I would like to thank for sharing his knowledge and experience. I am also very grateful for the opportunity to pursue this research topic.

I would like to express my special thanks to Professor Mark H. Chignell for his valuable advice and support, for his interest in my work and for always making time available for me. I am particularly grateful for his advice in experimental design and statistical analysis.

I would like to thank Professor David Sadleir for his advice and time.

Thanks to Rick Bodner and Kitman Cheung who helped with the preparations to my experiment.

Thanks to the Interactive Media Group (Haig Baronikian, Rick Bodner, Rick Kopak, and David Modjeska) for their advice and many creative discussions.

I would like to thank a fellow student, Katayoun Atefi, for her advice and many valuable discussions.

I would like to acknowledge excellent system support at UTMIE. Thank you Oscar Del Rio.

To my parents, Alina and Stanisław Gwizdka, my greatest thanks for their love, support, and for instilling in me the desire to seek knowledge. Dziękuję!

This research was supported, in part, by PRECARN Associates, and Spar Aerospace.

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Chapter 1

Introduction

“I keep six honest serving-men
(They taught me all I knew);
Their names are What and Why and When
And How and Where And Who.”
Rudyard Kipling, "The Elephant Child"

1. Introduction

Engineering information recorded in paper engineering notebooks is difficult to access, since paper notebooks do not facilitate information retrieval. This thesis addresses the problem of capturing engineer's notes into an information system and structuring them to facilitate information access.

The focus of the thesis is on non-intrusive methods of structuring information. As a solution we propose a free-form interface with semantic information structuring. Software implementation of our interface is running on a pen-based notebook computer. We call our system Electronic Engineering Notebook, or EEN for short. We view EEN as an individual engineer's tool used to take notes.

The representation used by us for structuring design information corresponds to engineering concepts. Our goal was to achieve "naturalness" and non-intrusiveness of the tool, rather than expressiveness of the representation. In our approach, we do not attempt to alter the design process. We provide designers with a computationally enhanced version of a traditional tool - an electronic version of an engineering paper notebook - that they are used to work with. Structuring of EEN content is then performed incrementally over time.

2. Description of the Problem

Engineering projects produce large amounts of information. This information is generated throughout all stages of the design process. It comes from different sources and is recorded in various media. This diversity make it very challenging to handle engineering information. The difficulty of the challenge increases in large engineering teams distributed over large geographical distances. Furthermore, we know that information is important to engineers; it is used within a project's life-cycle, it is used across different projects and it is re-used from past projects. Previous studies in the Enterprise Integration Laboratory [Crabtree et al. 1993] confirm this importance. The results indicate that engineers spend a significant portion of their time (34.5%) on information related tasks, and that lack, or insufficient information acquisition and access, cause substantial number of coordination problems (56%) in engineering projects, for example, project delays.

Computer technology is introduced in a variety of ways to assist in effective capturing and managing of engineering information. However, not all the design stages can be computerized easily. Therefore, existing computer systems usually capture design only in its final form. Initial design is one of the design activities that is especially difficult to computerize, yet during this stage crucial decisions for the whole design process are often made and justified. Thus the initial design stage generates information valuable throughout the whole design process, as well as in the future design projects. In current practice, information created during this stage is, usually, recorded in paper engineering notebooks, or on the proverbial back of envelopes only, and, thus, it is difficult, if at all possible, to access. Engineer's activities at this design stage are exploratory, not highly structured, and are, quite often, characterized by mobility. The nature of these activities makes information capture difficult. In the analysis of potential solutions we need to consider both technological and human factors.

We first consider what kind of technology could be used to implement information capture during initial design. Given their widespread use, and engineers' familiarity with paper document technologies, the first possibility is to use an elaborate paper-based system. However, paper-based systems, even well organized, are not easily accessible. Their access from remote locations is usually not possible without human intervention. The next possibility is to use a hybrid approach, combining paper and computer technologies; paper to record information, similarly as it is currently practiced, and computers to manage the recorded information [Wellner 1993]. This type of solution is not very practical. It is laborious to track information changes; entering new information and updating modified documents in the system requires extensive human assistance. Furthermore, the granularity of access level is very coarse, and system setup is cumbersome.

In contrast to paper-based and hybrid technologies we will examine how initial design information capture could be supported by a wholly computer-based system. The primary guideline for introducing computer-based solution is that it integrates well with the current practices and that it is non-intrusive. Satisfying it requires understanding how information is created during the initial stages of design.

An engineer's interaction with paper notebooks is free-form, that is, no constraints are imposed by the media on the created elements, for example, on handwritten scribbles or drawings; these elements can be written anywhere on a page. Structure of the free-form content is defined by spatial relations among the elements on a page and by marks, which quite often are adopted by each individual separately. Hence the structure is, for the most part, implicit, and, together with semantics, it is created, by the human interpretation of the recorded content. Providing computer support for accessing the captured design information requires the system to "understand" the recorded content, for example, to understand specifications of requirements, parts, parameter values, issues, and the like. Making the system "understand" these specifications should be a key step in supporting human information processing and interaction with the system. Thus the structure and semantics of the recorded notes need to be made explicit.

At the same time, when obtaining structured content, we would like to preserve the free-form interaction style. The conflict between free-form interaction and structured content with semantics is paralleled by the conflict between implicit and explicit knowledge. This conflict can be resolved by delaying structuring of free-form content. Hereby allowing the possibility for coexistence of both free-form, and structured information in one medium. Implicit structure and semantics cannot be made fully explicit during the information creation, since structuring would disrupt the flow of the creative processes and since structuring would simply take too much time. By delaying structuring we avoid this problem. Structuring can be performed after note-taking activities and when designers become conscious of their thinking as it occurs during breakdowns in the unself-conscious process of design. More structure and modifications to existing structure can then be added later. The choice of representation elements used to structure the initial design information should correspond to concepts used by engineers and their natural modes of expression.

Striving to achieve non-intrusiveness of a system capturing initial design information is not the only possibility. Many systems that capture design information, and especially design rationale, require designers to follow specific procedures. These procedures are devised to influence design practice in such a way that designer thinking, at least to some degree, becomes explicit and thus possible to capture. Some authors (for example, [MacLean et al. 1993], [Buckingham et al. 1994]) claim that by imposing these special procedures on designers' processes their work becomes better structured and designers are able to examine the design space more systematically. In our approach, however, we do not attempt to alter the design process itself.

3. Thesis Objectives

Our high-level goal is to improve access to design information by engineers. Within this goal we set out the objectives of this thesis as:

1. to design and develop an electronic notebook system for non-intrusive acquisition of design information that provides capability to semantically structure information using engineering concepts,
2. to examine usability of the suggested free-form interface and compare it with a fixed-form interface from the point of view of capturing and structuring recorded information,
3. to ascertain suitability of terminology based on engineering ontologies to semantic structuring of engineering notes.

4. Research Expectations

We formulated research expectations in the area of note-taking, structuring notes, and information retrieval from notes.

Our first expectation is that note-taking style afforded by a free-form interface is closer to note-taking on paper, and thus, that a free-form style interface is more natural, and therefore easier to use than a fixed-form interface. We expect that a more natural free-form interface allows for quicker note-taking and that resulting notes are “better”, that is more complete.

Semantic structuring involves two steps: applying the structuring mechanism and deciding to which semantic category information belongs to. We expect that performing structuring and taking notes at the same time is difficult, and thus, that delaying structuring is beneficial. Furthermore, we expect that performing semantic structuring employing user-defined terminology is easier than using pre-defined categories. In addition, applying categorizations should be easier for “expert” users.

Similar effects of user-defined terminology and expert use should be observed during information retrieval from notes. We expect information retrieval based on user-defined terminology to be easier and more effective. Furthermore, experts should be able to better use categorizations during information retrieval from notes.

Detailed description of research expectations and hypotheses is provided in Chapter 4, section 2.

5. Thesis Overview

In Chapter 2 we present background information and review the related work. Chapter 3 describes the design of the Electronic Engineering Notebook system and domain-based labels used for semantic structuring of free-form information. In Chapter 4 we describe conducted experiments, as well as analyze and discuss their results. Finally, Chapter 5 presents conclusions and points out directions for the future research.

Chapter 2

Background and Review of Related Work

"There is something fundamentally compelling in grasping structure, a sense that something of significance has been revealed, some deeper meaning."
Steven R. Holtzman, "Digital Mantras"

"...one of the hallmarks of design problems is that they require extensive structuring."
Goel and Pirolli from "Motivating the Notion of Generic Design Within Information-Processing Theory"

1. Introduction

The focus of this thesis is on structuring design information and facilitating access to it. There are many approaches differing in time of applying structuring and in object of structuring. We define design information as composed of design process information (requirements, decisions, rationale, dependencies), design artifact information (parts, parameters, values, features), and project management items (issues, actions, goals).

2. Structuring Design Information

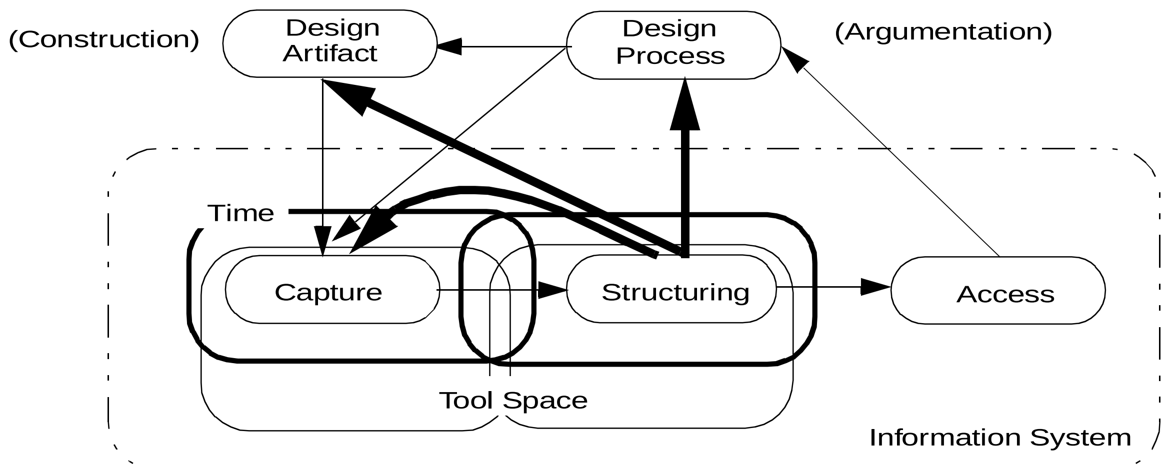
Information in its life-cycle exists outside and inside an information system. An information processing system is not synonymous with a computer system, for its implementation can range from paper-based filing system to complex distributed computer system. Information is created and used outside the system, and is stored and processed inside the system. Information flow inside the system can be divided into three stages: information capture, information structuring[1] and information access. Relationships among these three stages can be characterized along the time and tool space dimensions. We focus on relations between capture and structuring. Information structuring and capture can take place simultaneously, or structuring can follow capture in time. In addition, marking elements and classifying them in structuring can also be separated in time. The same tool, or two different tools can be used to capture information and to structure that information. We can further characterize information structuring by describing what is being structured. The object of structuring can be a design process or the information created by that process.

The design process involves construction and reflection about design [Schön 1983]. Construction includes actions involved in shaping the solution ("knowing-in-action" - a term coined by Donald Schön), and it "produces" the structure of an artifact being designed. Reflection involves reason-

1. Structuring is used here in a sense of semantic structuring, which involves two steps: marking elements of captured information and attaching semantic categories.

ing about action ("reflection-in-action"), it "produces" argument structure (design process structure). Construction[1] and structuring can be performed within the same or separate tools. This model is depicted in Figure 1.

Figure 1. Structuring in design information life-cycle[2]



Our review of related work is guided by the framework described above.

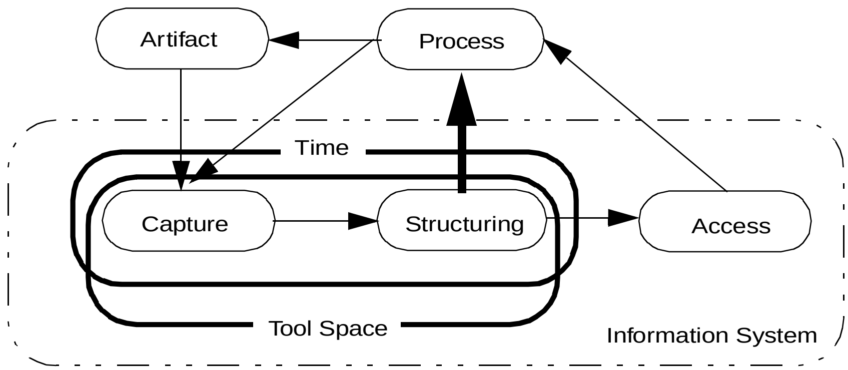
2.1 Shaping the process

The first group of methods and tools aims to shape the design process. Designers follow procedures that systemize their thinking with the intent of improving the process. The design process is structured by guided exploration of the design space. Different methods cover elements from various design sub-spaces (e.g. argument, alternative, criteria, evaluation, and issue sub-space) and their relations. This type of approach was originated by Rittel [Rittel 1972] in his work on Issue-Based Information System (IBIS). In these methods, design information is structured as a result of

1. Construction involves creating an external representation of an artifact being design. This representation can be recorded, for example, on paper or in electronic media, and can have a form of notes and drawings. In this work we are interested in capturing this representation. In this chapter construction is used in a sense of actions creating the external representation that is being captured.
2. The diagram represents elements of an information system from the user interaction perspective. Other components of an information system (e.g. storage), not evaluated directly in this research, are not shown. However, a storage model was designed and implemented in the EEN (see Chapter 3).

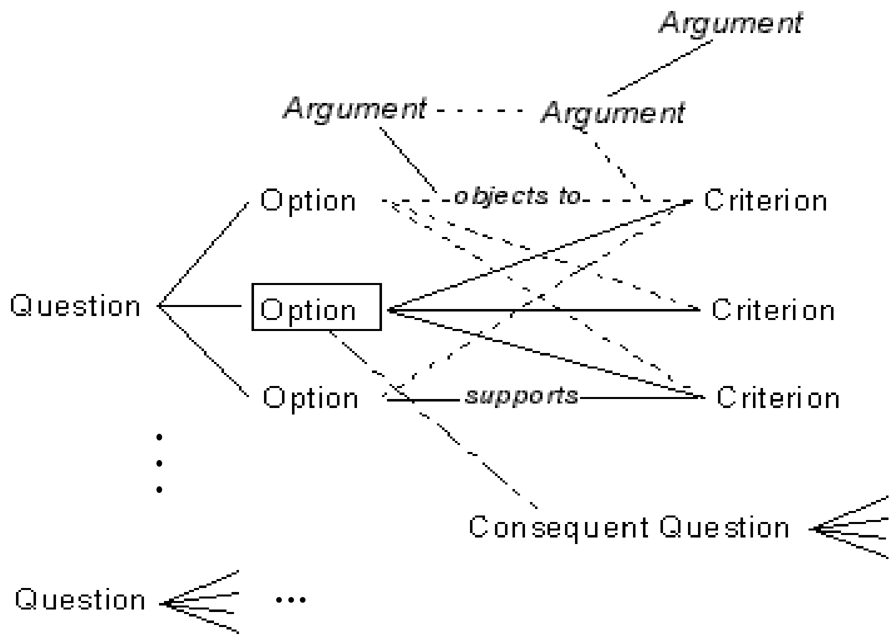
structuring the process. Capture and structuring are performed at the same time, and using the same tool (see Figure 2).

Figure 2. Shaping the process



QOC ([MacLean et al. 1991], [MacLean et al. 1993], [Buckingham 1996]) is an example of a semi-formal argumentation-based methodology of this type. QOC stands for *Questions, Options and Criteria* which are used to systematically represent and reformulate the design space. *Questions* are used to express key issues in the design, o*ptions* are alternative answers to *questions*, and *criteria* are appealed to in choosing one *option* over another. In addition, *assessments* represent relationships between *options* and *criteria* (there are two types of assessments: *supports* or *objects-to*), while *arguments* can be used to debate the status of assessments. These elements are summarized in Figure 3. Boxed *options* are used to indicate a design *decision.*

Figure 3. The vocabulary of QOC used to represent design space



QOC is used to analyze design space by discovering dimensions of a space (*questions*?), of exploring the space of alternatives (*options*), of justifying why one point in a space is better than another (through *criteria*, *assessments*, and *arguments*) and then making *decisions*. QOC does not require a high-tech solution; it can be implemented using paper forms. For recording rough QOC a sheet of paper consisting of three columns (for Questions, Options and Criteria), and a working area (for not immediately classified ideas) could be used.

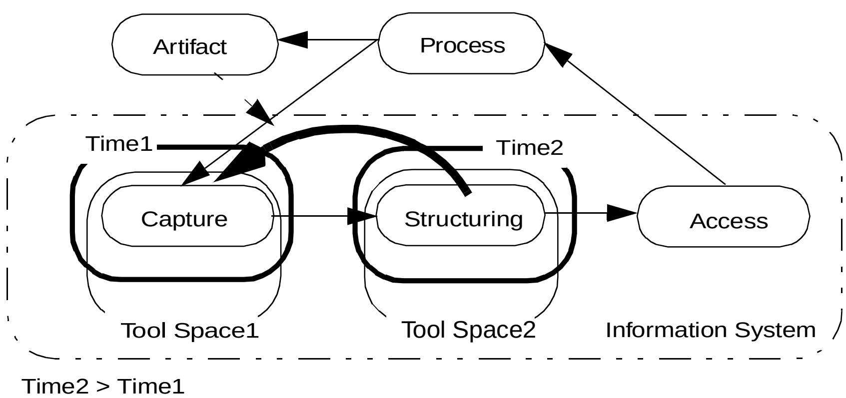
The value of QOC, and similar approaches (in design domain: DRL [Lee 1991], gIBIS [Conklin et al. 1988], a collection of various approaches [Moran et al. 1996], and in other domains: Toulmin structures [Toulmin 1958], [Newman et al. 1991], argument structures for writing [Schuler et al. 1990], [Streitz et al. 1989]), come from supporting focused exploration of the design space. However, experiences with QOC, and other methods in performing capture and structuring of design information at the same time, provide common results showing that designers have significant difficulty structuring their thinking while working on design tasks [Buckingham et al. 1994]. Designers also have considerable difficulty in expressing their arguments when forced to use an argumentation schema. On the other hand, it has been shown that the representations used in these methods are adequate for structuring design information, as described in the next section.

2.2 Separating construction and structuring of design information

In our approach, we stress non-intrusiveness and strive to perform structuring without changing the design process. Thus structuring design information is separated in time from its creation. There are two groups of systems following this approach. In the first group, design process is first captured and then structured (Figure 4); in the second both artifact (its appropriate representation, e.g. drawing) and process are captured and subsequently structured in a different tool (Figure 5).

While the methods described in the previous section are difficult to use in capturing design information in real design setting, the techniques and representations employed in them can be used in post-generation analyses. For example, QOC was used not only during the design process, but also afterwards [Shum et al. 1993]. It was generated a posteriori from the recorded design sessions and design documentation to gain better understanding of the design process. Such a use is time consuming and costly.

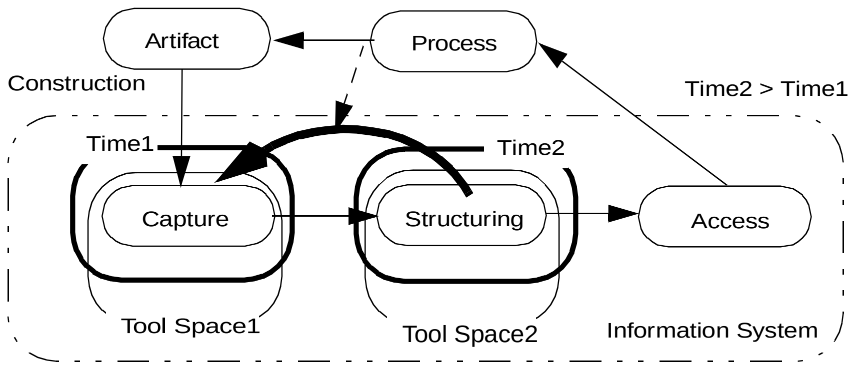
Figure 4. Post-structuring the process



In the work described so far, structure of the design process was captured along with some related artifact elements; structure of the artifact was not recorded. In other approaches, a model of design artifact was used to structure earlier captured design information (Figure 5). As reported in [Baudin et.al. 1993], a body of documents from a design project was manually structured and indexed with domain model terms. The authors demonstrated resulting improvement in information retrieval over boolean text search.

In this thesis, we are interested in ascertaining the suitability of a subset of a similar domain representation applied by designers to structuring their design notes in an electronic notebook.

Figure 5. Separation of construction and structuring



Although dubbed "notebook", MECE (Multimedia Engineering Collaborative Environment [MECE 1995]) is more like a hypermedia authoring tool with shared publishing (and thus we do not group it with other electronic notebooks, which are discussed in section 2.4.1). Entries can be composed of text and pre-existing images, audio and video clips. Each entry has a structure composed of basic information (authorship, description) and content structured by concepts from domain representation. Entries have types and keywords associated with them. The authors do not provide information as to whether types are based on pre-defined domain concepts or on user terms. Users can define a hierarchy of keywords for each design project. MECE contains a keyword manager which maintains the hierarchy of keywords, their definitions, and synonyms. From the examples of use provided, the combination of concepts from domain representation and user-defined terms for indexing design information seems promising. However, no detailed studies are reported.

In [Klein 1997] Klein reports on a continuing effort to develop a design representation capturing artifact structure and design process. He presents the system's user interface (C-DeSS). Construction, in a sense of defining artifact's geometry, is performed using standard CAD tools. The drawing is then structured by defining and naming geometry features. The resulting pre-structured image is subsequently structured within the C-DeSS interface by attaching elements from the representation to artifact's features.

Separating tools used for construction and structuring increases the gap between the two activities and complicates the process. While tools employed in practice (e.g. CAD software) may impose such a separation, our interest is in integrating construction and structuring.

2.3 Documenting design - form-based interfaces

Design documentation, created after performing the design, can be seen as a kind of post-structuring of design information. However, documentation is quite often produced retrospectively. The typical motivations for creation of design documentation are management or outside use, or legal requirements to secure intellectual property generated in a project. Both supervisory and legal purposes do not require recording all design reasoning, and thus, most often, only the final design information is recorded and the whole design process is lost.

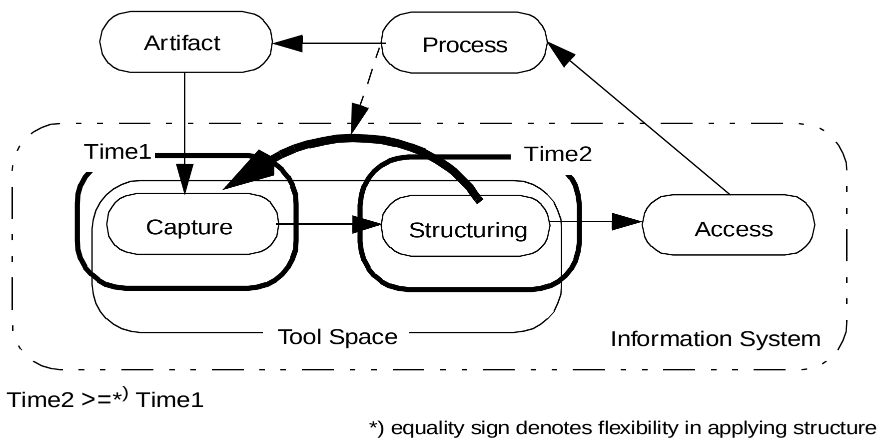
Periodic reports are a prevalent form of documentation. Such reports often require filling out special forms where particular subsets of design project information are briefly described and in more or less constrained formats. Paper is the most common medium used for design documentation. Even when computer support for documentation is available, it is generally limited to static data-entry forms. A novel concept, dynamic forms, is suggested in [Girgensohn et al. 1995]. Dynamic forms that hide fields not applicable to the current situation and identify fields still needing attention may make the documentation task less onerous. However, the dynamic features of these forms require pre-programming, and, thus, this solution is appropriate for well-structured and repeatable tasks.

Forms, if used during the process, become an example of an interface in which structuring is performed during information capture (see section 2.1).

2.4 Non-intrusive capture and structuring

In the above reviews, we pointed out the difficulties arising along the time and tool space dimensions relating information capture and structuring. We suggested that separation in time, and integration in the tool space, are essential for non-intrusive capture and structuring of design information (Figure 6). Tools built with this approach in mind belong to a class of electronic notebooks that use delayed structuring. The degree of non-intrusiveness varies with the type of user interaction supported (pen-input, keyboard input) and with the method of structuring (e.g. capture involving marking of structural elements and delayed classification, versus full delay of structuring).

Figure 6. Integration in space and separation in time of construction and structuring



2.4.1 General purpose personal electronic notebooks

Several systems have been developed for indexing and structuring information in personal electronic notebooks.

In Dynomite [Wilcox et al. 1996] properties describing type of information can be assigned to handwritten notes and user-defined keywords to pages. The system has a set of pre-defined general purpose properties, other can be added by users. Proteus [Erickson 1996] uses “stamps”[1] to mark notes. The author noted that cognitive overhead associated with applying stamps prevented them from being used in practice.

Although keywords, or other structuring elements, are employed in these electronic notebooks, empirical studies on keyword terminology usage and on its effects on information retrieval strategies are generally lacking.

2.4.2 Electronic Design Notebooks

In [Hong 1995] the authors present PENS (Personal Electronic Notebook with Sharing)- a lightweight notebook for designers. PENS supports note-taking, browsing, and sharing notes through the Internet. It is essentially an off-line Web-authoring tool with browsing capabilities. The keyboard is the only input device. Notes are shared by weaving their contents and structure onto a group notebook located on the WWW. Structuring notes is performed by assigning them user defined categories; only four categories can exist simultaneously, if more are needed a new notebook has to be created. The authors do not report on the use of terminology for categories, nor on managing the shared notebooks’ categories.

Electronic Design Notebook (EDN - [Lakin et al. 1989], [Lakin et al. 1992]) was an earlier effort in the same research center (Stanford’s Center for Design Research). In EDN designers create design information using a desktop computer with pen-tablet running vmacs-EDN software. Information structuring is performed by adding user keywords called “idea-tags”. Tagging is performed with visual markers. To allow for mapping between the designer-centered view (expressed by idea tags) and the organizational view of a design, a translation table is created by a knowledge engineer (or by a designer). This translation table is based on the particular designer's notebook habits and design ideas. In the design information access stage, user queries can be expressed both in designer’s terms and in organizational terms (requirements). Terminology use is not reported.

1. Stamps are textual or graphical labels used to mark notes.

In earlier work on EEN in our research laboratory (Enterprise Integration Laboratory at the University of Toronto) [Louie 1995], Louie focused on design information acquisition. In a series of three studies he compared paper and electronic notebook with regard to reading, writing, and sketching activities. In reading and sketching both media were found to be equally good; in writing, paper was a better medium. Three versions of electronic notebook hardware differing in screen size were tested, the larger the screen the better the reading and sketching performance was observed. The focus of this thesis is on design information structuring. Furthermore, we developed an EEN with extended functionality (see Chapter 3).

The Electronic Engineering Notebook described in this thesis integrates construction and structuring, while allowing for delayed, incremental structuring - both unstructured and structured information can co-exist.

2.5 Conclusions

Support for non-intrusive capture of design information and delayed structuring within the same tool space is not addressed well in other work.

Domain representations were used in previous work to structure design information. The process of structuring was, however, either not separated in time from information capture or, if separated, it was performed by using separate tools.

On the other hand, while previous work on electronic notebooks is similar to ours along the time and tool space dimensions, empirical studies on terminology used to categorize structured design information and on its effects on subsequent information retrieval strategies are generally lacking.

Furthermore, non-intrusiveness of electronic notebooks is not only determined by relation of information capture and structuring in time and space, but also by the type of supported interaction. Most other electronic notebooks did not employ free-form interaction paradigm and did not support pen-based input (the exceptions were Dynomite and EDN).

Chapter 3

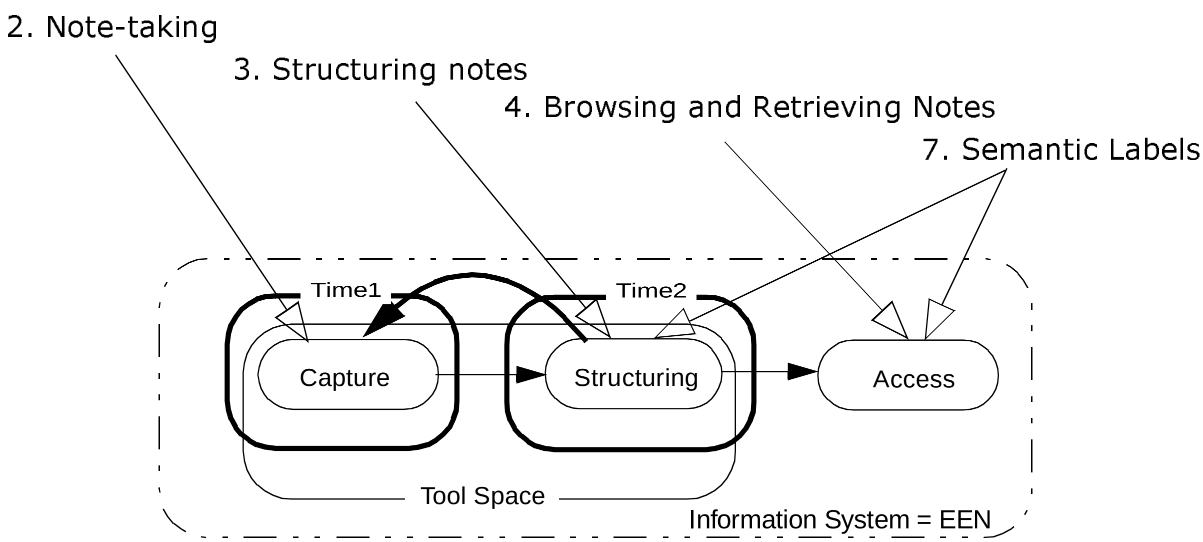
Design of Electronic Engineering Notebook

"Any sufficiently advanced technology is indistinguishable from magic."
Arthur C. Clarke, "The Lost Worlds of 2001"

1. Overview

We described earlier (Chapter 1, Section 2.) the difficulties that engineers have in acquiring and accessing design information. We also stressed the importance of this information in the engineering process. The goal of this work is to improve access to design information by engineers. As part of the thesis (see thesis objectives outlined in Chapter 1, Section 3.) we designed and developed a system for non-intrusive acquisition of design information that provides capability to semantically structure this information using engineering concepts, and makes it available for retrieval. The system is called Electronic Engineering Notebook, or EEN for short.

Figure 7. Organization of Chapter 3[1]



The main functions of the EEN are information capture (presented in Section 2.), indexing and structuring (see Section 3.), and information access (see Section 4.).

1. Text and symbology used in this figure is introduced in Chapter 2.

The EEN has three interface variants called: FFP, FFU, and FORM (Table 1).

Table 1: EEN interface variants

Symbol	Explanation
FFP	Free-form interface with pre-defined terminology for semantic structuring
FFU	Free-form interface with user-defined terminology for semantic structuring
FORM	Fixed-form interface with pre-defined terminology for semantic structuring

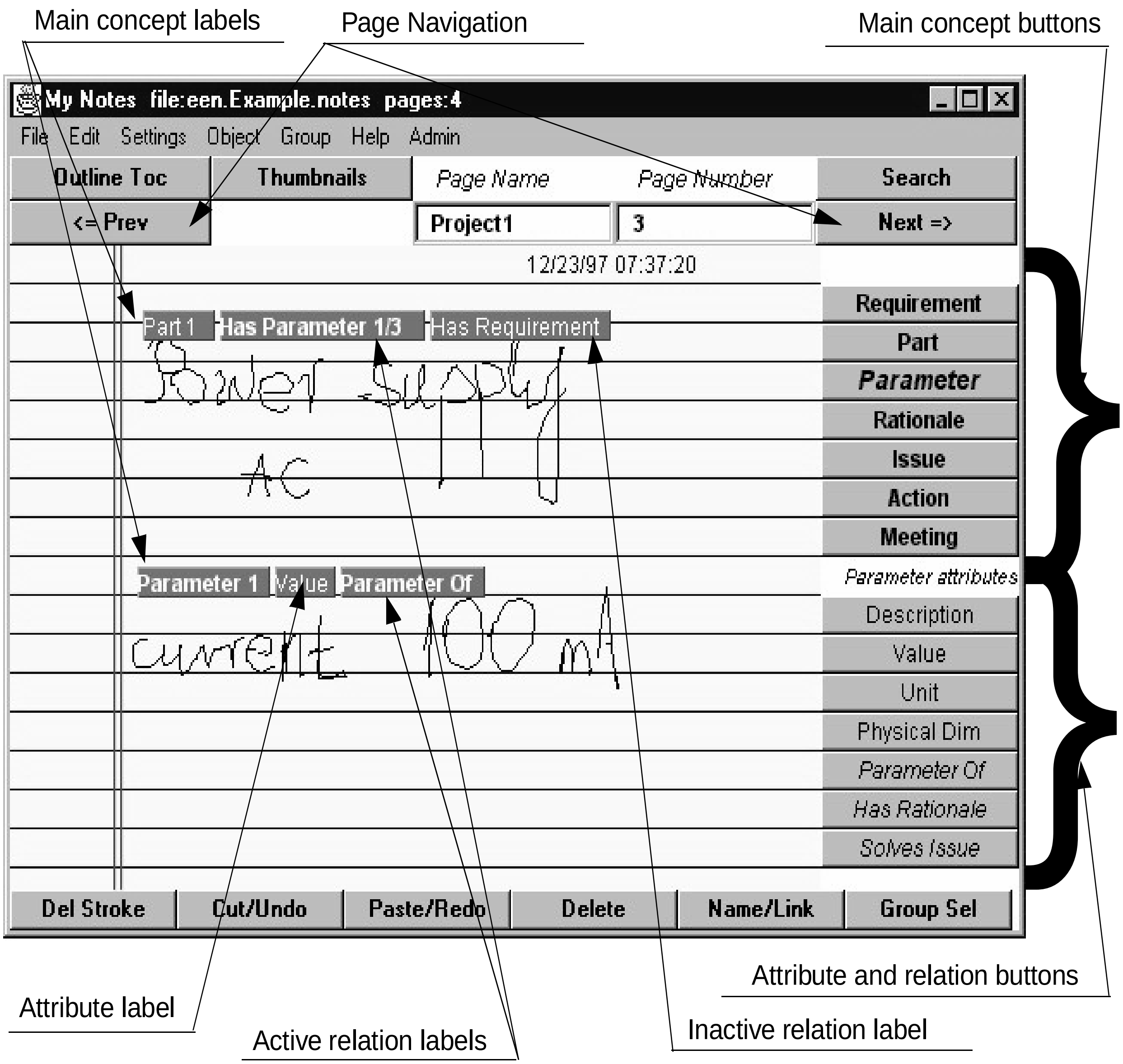
Sections 2.- 4. describe FFP and the common elements to all interfaces, while Section 5. and Section 6. focus on the differences in FFU and FORM, respectively.

2. Note-taking - Capturing Information

In order to achieve non-intrusiveness we incorporated natural note-taking features of traditional paper engineering notebooks. In the design of the user interface for EEN we employed the familiar notebook metaphor, including methods of organizing information (e.g. pages, table of contents). Support for natural user interaction was complemented by using pen-based input.

Elements of the notebook metaphor give EEN the “look and feel” of a notebook. These elements include: visual appearance, interaction style and information organization. We describe the latter in detail in the following subsection (Section 3.). The visual appearance of EEN user interface is similar to a paper notebook’s page with added controls for navigation and indexing (see Figure 8).

Figure 8. Free-from EEN User Interface with Pre-defined Labels (FFP)



Users interact with EEN using pen input. The input is free-form, that is, users can write or draw anywhere on the electronic notebook page and the system does not impose any constraints on where the information can be entered. The objects created by users are called *free-form objects*; we refer to them using abbreviation *FFO* hereafter.

Definition 1

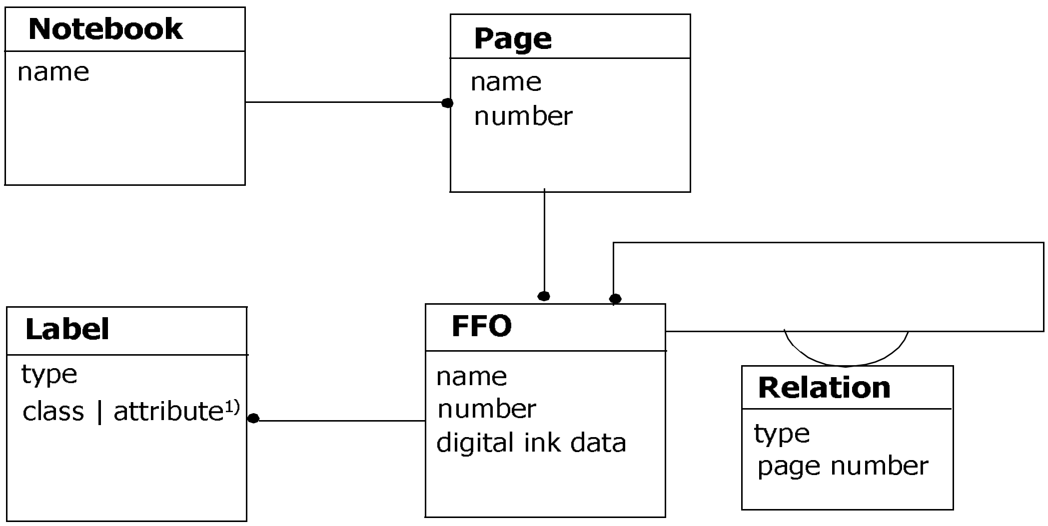
Free-form objects are two-dimensional objects that can be created anywhere within an input area of an electronic notebook page. FFOs can be in the form of handwritten scribbles, typed text, as well as can be created from predefined elements.

EEN supports handwritten and typed text FFOs. Handwritten FFOs are composed of elementary pen strokes, which are stored by the system as *digital ink*.

Definition 2

Digital ink is an internal representation of pen strokes. The representation contains the coordinates of each stroke, and optionally, characteristics of pen, such as color and thickness of pen. They can be user defined or come from pen-input hardware, for example, pen thickness can be controlled by a pressure sensitive pen device.

Figure 9. EEN Internal Data Architecture (in OMT notation)



1) FFO can have one class label and multiple attribute labels

Figure 9 presents EEN's internal data architecture. A notebook can have multiple pages, which in turn, can have multiple FFOs. FFOs can have attached labels, one main concept label and multiple attribute labels. FFOs can be linked by semantic relations. Labels are described in more detail in Section 3. The terminology used in labeling is presented in Section 7.

Users can perform several operations on FFOs. The operations include move, cut, paste, delete, and group. In handwritten FFOs, single pen strokes can be erased. The operations can be described in the BNF notation as follows:

<1arg_operation> := <1arg_operator> (<selected FFOs> | <last created FFO>) (EQ 1)

<1arg_operator> := move | cut | delete | group (EQ 2)

<paste_operation> := paste (EQ 3)

<selected FFOs> := FFOs selected by dragging a election rectangle (EQ 4)

<last created FFO> := the last FFO created by user (EQ 5)

Operators are applied to arguments (FFOs) which are selected first. Selection of FFOs is performed by dragging a selection rectangle over the desired FFOs. Operators are selected from a pull down menu located at the top of the display. Paste function operates without an argument.

Shortcuts, in the form of buttons located at the bottom of display, are provided for the most common operators (see Figure 8). In addition to the above typical operations, FFOs can be tagged by using labels.

<tag_operation> := <tag_operator> (<selected FFOs>) (EQ 6)

<tag_operator> := <main concept label> | <attribute label> | <relation label> (EQ 7)

<main concept label> := Requirement | Part | Parameter | Rationale | Issue | Action | Meeting (EQ 8)

<attribute label> := <attribute labels depend on the selected main label> (EQ 9)

<relation label> := <relation labels depend on the selected main label> (EQ 10)

Tag operators are selected by using one of the label buttons on the right-hand side of the page. Labels are described in more detail in Section 3.

Another important factor to be considered when providing non-intrusive information acquisition is hardware technology. Our EEN is designed to be used in a light-weight, pen-based, mobile computer with wireless communication.

For the purpose of this thesis work, we relied on currently available commercial hardware solutions. We can expect that as newer technology becomes available, smaller, lighter devices with more natural pen input will come to the market. Our EEN software is ready to use their features.

3. Structuring Notes - Making Information Understandable

Once the content has been created in the process of capturing information, it has to be made understandable to the system. We do not rely on handwriting or sketch recognition. Instead we make the meaning of the content explicit to the information system by the process of semantic structuring[1]. Our purpose of making the content explicit to the system is to support information finding by its users.

1. Levels of structured content in electronic notebooks with free-form interaction are described in Appendix A.

Each FFO can have attached one main label describing the class of information and any number of specializing labels (attribute or relation labels). Our model of classifying information is analogous to an object-oriented model. Semantic labels are divided into three groups:

1. main labels- specify class of information which describes the main concept contained in an FFO
2. attribute labels - specialize information contained in an FFO
3. relation labels - link related pieces of information (FFOs)

For example, in Figure 8 the first FFO ("Power supply") is marked with the main concept label "Part", and has two relations attached: "Has_parameter" and "Has_requirement". The second FFO ("current 100mA") is marked with the main concept "Parameter", with attribute label "Value", and has a relation label attached "Parameter_of".

The process of semantic structuring involves two steps. First, an element of structure is marked by selecting a single FFO or a group of FFOs. Next a semantic label is attached to the marked element by tapping on a main concept button. Grouped FFOs are handled as one FFO[1]. Further structuring of the content takes place by adding more labels and by adding links between labelled FFOs. This is done by means of *concept sensitive labelling* of FFOs.

Concept sensitive labelling means that after attaching the main label to an FFO the system "knows" what other attributes and relations are appropriate for this main concept. A list of attribute and relation buttons with these labels is shown under the main label buttons (see Figure 8). Attribute labels and relation labels are added by selecting a labelled FFO and then tapping one of the attribute and relation buttons.

Creating links between labelled FFOs takes an additional step. After a relation label is attached to an FFO it needs to be linked to another FFO. Double tapping on a relation label opens an index of

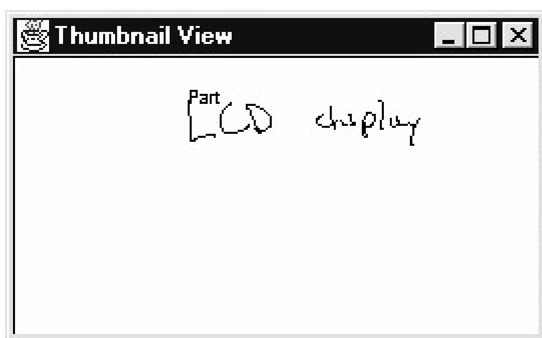
1. A marked structure element is thus the same as a labelled FFO.

all FFOs in a notebook labelled with main concepts to which this relation can be linked (Figure 10). Double tapping on an element in an index displays a thumbnail view of an FFO in the exact position on its page (Figure 11). Link to this FFO is confirmed by double tapping on it. We call this process *linking in context* since the destination FFOs are first viewed in the context in which they appear on a page. After performing the linking, relations become *active*, that is links can be followed by double tapping relation labels (see also Semantic linking on page 31).

Figure 10. Index with all "Part" labels[1] in a notebook

Text in active (i.e. linked) relation labels is displayed in a bold font (e.g. "Has_Parameter" and "Parameter_Of" relation labels in Figure 8). Text in inactive labels is displayed in a regular font (e.g. "Has_Requirement" in Figure 8). Links between FFO are bidirectional and make a typed, bidirectional graph with labelled FFOs as nodes.

Figure 11. ***Linking in context*** **- thumbnail view of a "Part"**



1. Terminology used in EEN's interface refers to labels as tags

Indexing and structuring of information is flexible and can be performed incrementally at any time, during or after creation of content. Terminology used for labels is taken from formal engineering ontologies. Further details are provided in Section 7. of this chapter.

Labels and links play an essential role in making the EEN content understandable, in capturing the design information, and in sharing the recorded information. They allow for indexing and structuring of design information recorded by engineers. They provide the means for the specification of parts, parameters, requirements, decisions, rationale, functions, issue, actions. The specification of engineering concepts makes the design information captured in the EEN accessible to engineers.

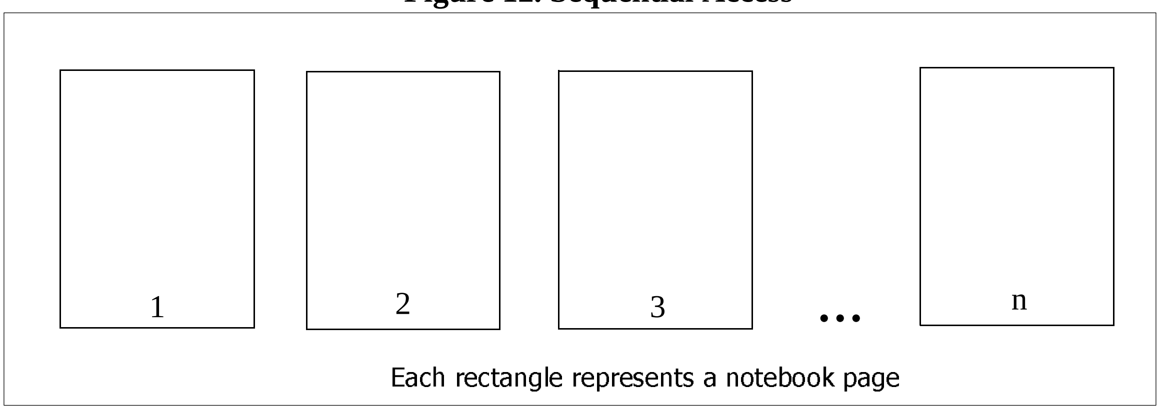
4. Browsing and Retrieving Notes - Information Access

The EEN gives four main ways to access information: sequential access, page name access, semantic index access and semantic linking.

4.1 Sequential access

In sequential access electronic notebook pages are accessed in the order they were created (Figure 12).

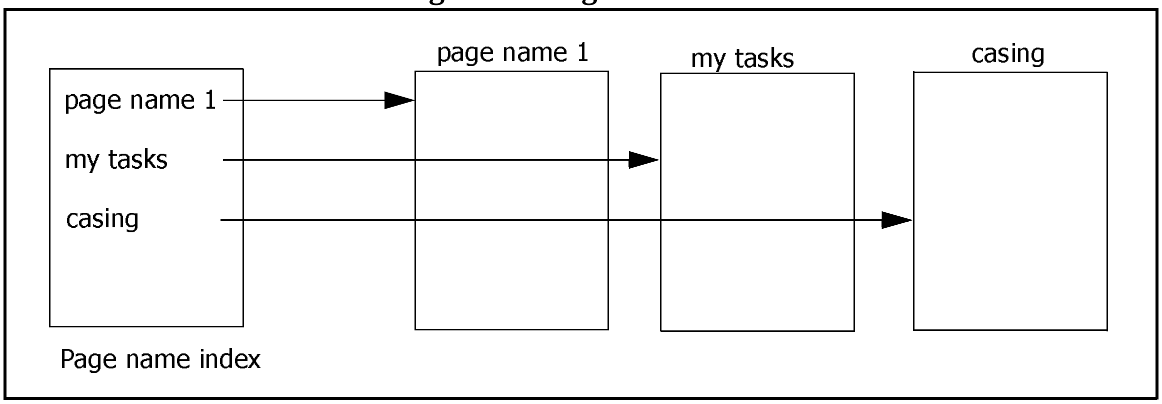
Figure 12. Sequential Access



4.2 Page name access

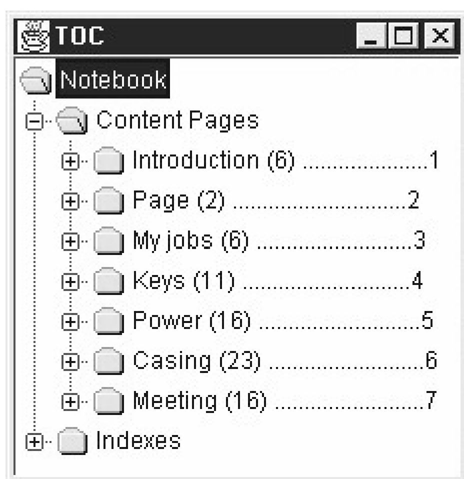
This mode allows to jump directly to a page with a given name. It is depicted schematically in Figure 13.

Figure 13. Page Name Access



Page name access is performed by using part of the EEN's table of contents (TOC) listing all pages (Figure 14). Each page name displayed in TOC is linked to a page and user can jump to this page by double tapping on the name.

Figure 14. EEN Table Of Contents (user page names)



4.3 Semantic index access

As in page name access mode, the user can jump directly to a page with a given label (Figure 15) in semantic index access. The mapping between concepts and pages is ambiguous, since one concept can be attached to many FFOs on many different pages. Therefore, the EEN provides a method of selecting pages after selecting a concept. Semantic index access is performed by using part of the EEN's table of contents, which lists all main concepts (Figure 16). Under each concept a list of pages is displayed that contain this concept. Using the same mechanism as described in page name access, user can jump to a page by double tapping on its name.

Figure 15. Semantic Index Access

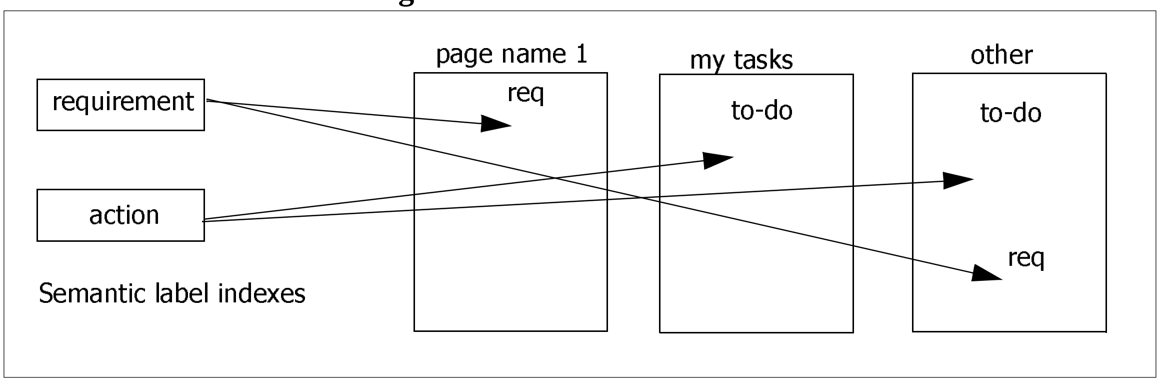
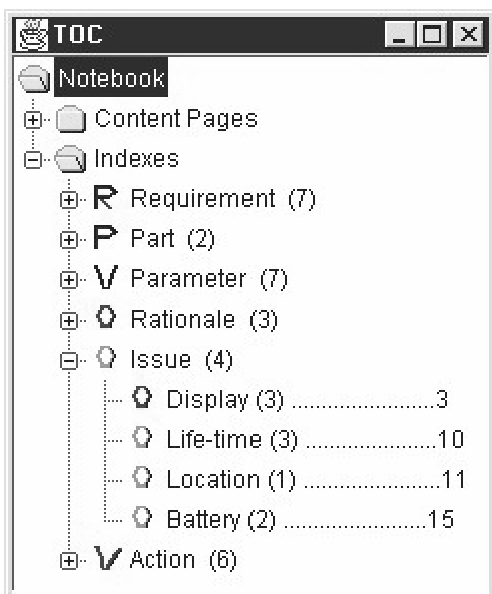


Figure 16. Table of Contents (main concept indexes)



Instead of using the main table of contents, user can first select the main concepts and page names in a search dialog (Figure 17). The system then gives access to a subset of the notebook, by creating a table of contents comprising only these pages that match the query (Figure 18). Access to pages is then performed in the manner described before.

Figure 17. EEN Search Dialog

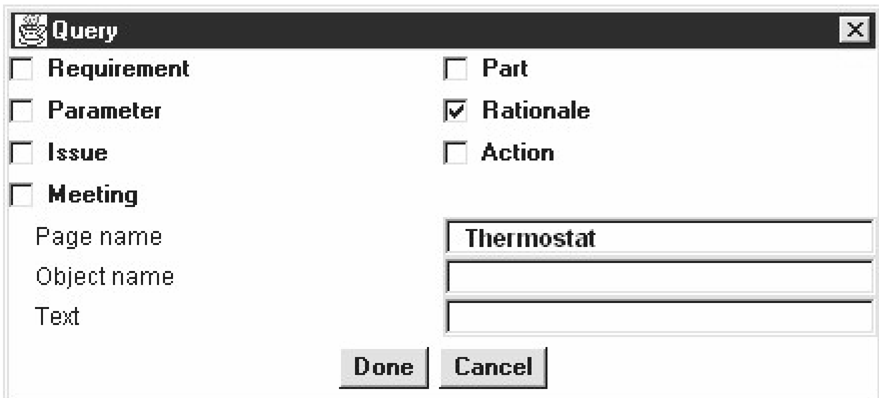
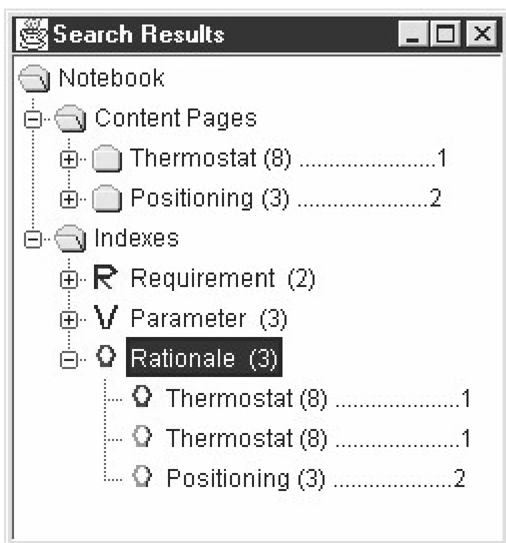


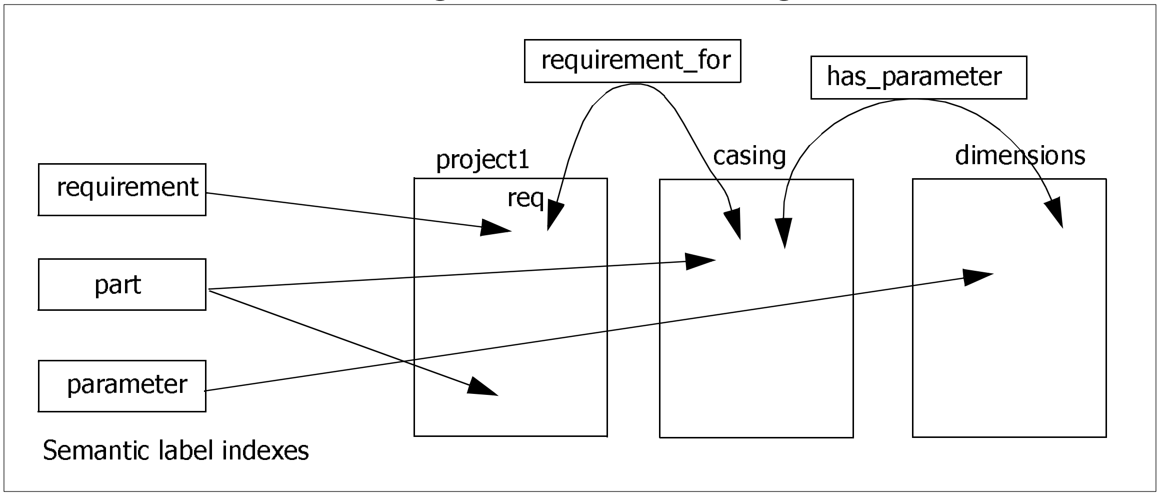
Figure 18. Search Results



4.4 Semantic linking

Semantic relation labels attached to FFOs are active, in a sense that user can follow the links from one FFO to another by double tapping on the relation labels (Figure 19).

Figure 19. Semantic Linking

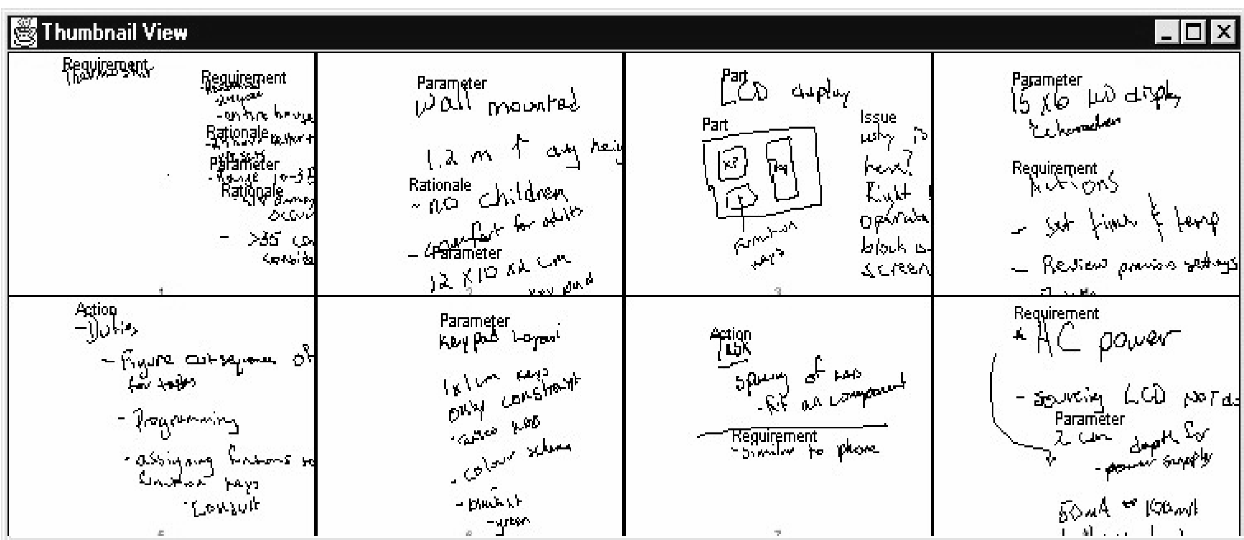


4.5 Other methods of access

EEN allows users also to jump directly to a page with a given page number which is entered into the page number field at the top of page display (Figure 8).

To support quick visual scanning of the content, EEN provides thumbnail views (Figure 20). Any page can be quickly accessed by double tapping on its small image.

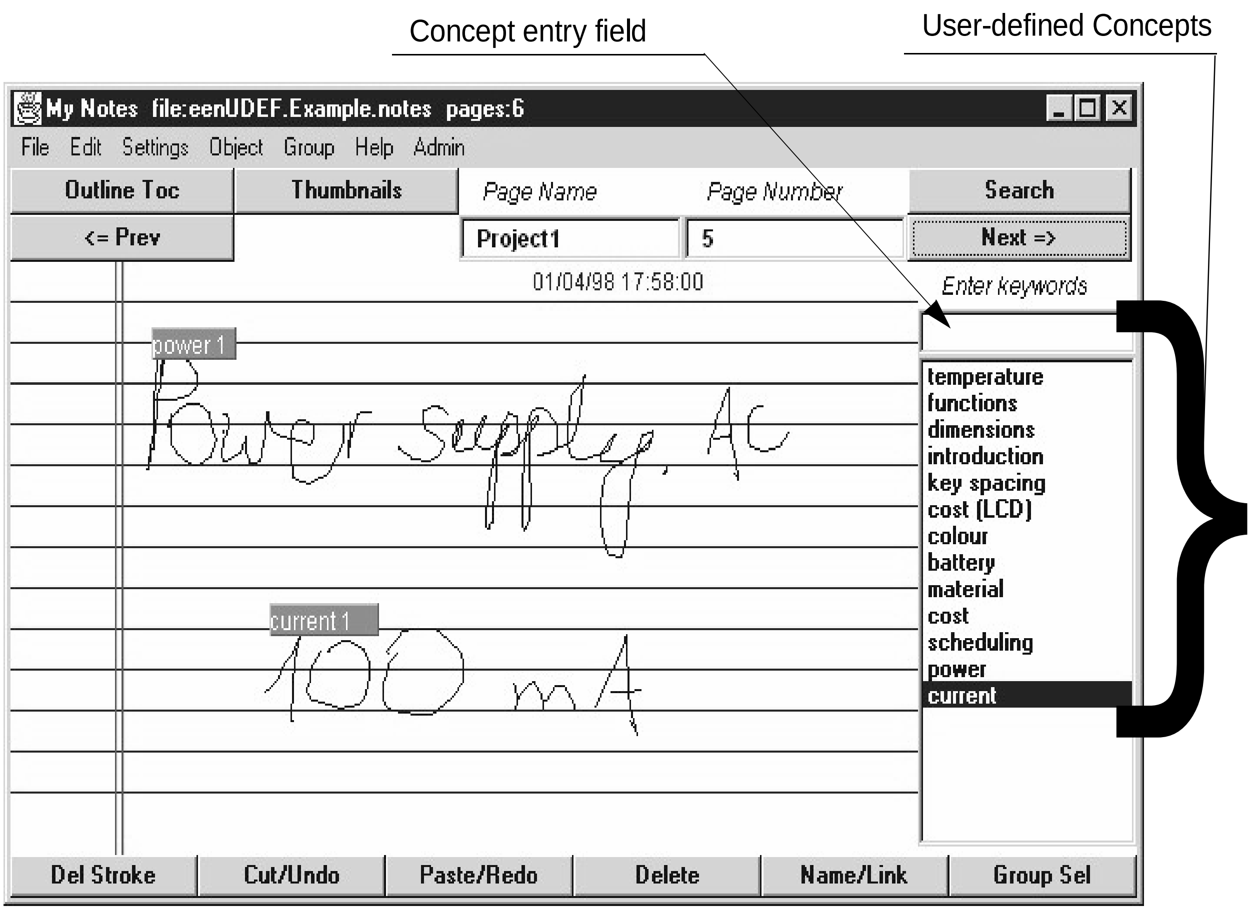
Figure 20. Thumbnail view



5. EEN with User-Defined Labels

The second interface variant (FFU, see Figure 21) is also free-form, but with user-defined, instead of domain-based, terminology used for labels. New terms are entered using keyboard input into a concept entry field. Labels with concepts can be attached to FFOs similarly as described in Section 3. All labels in the FFU interface are main labels. No attribute or relation labels can be defined. Mechanisms for browsing and retrieval of notes are the same as those described in Section 4.

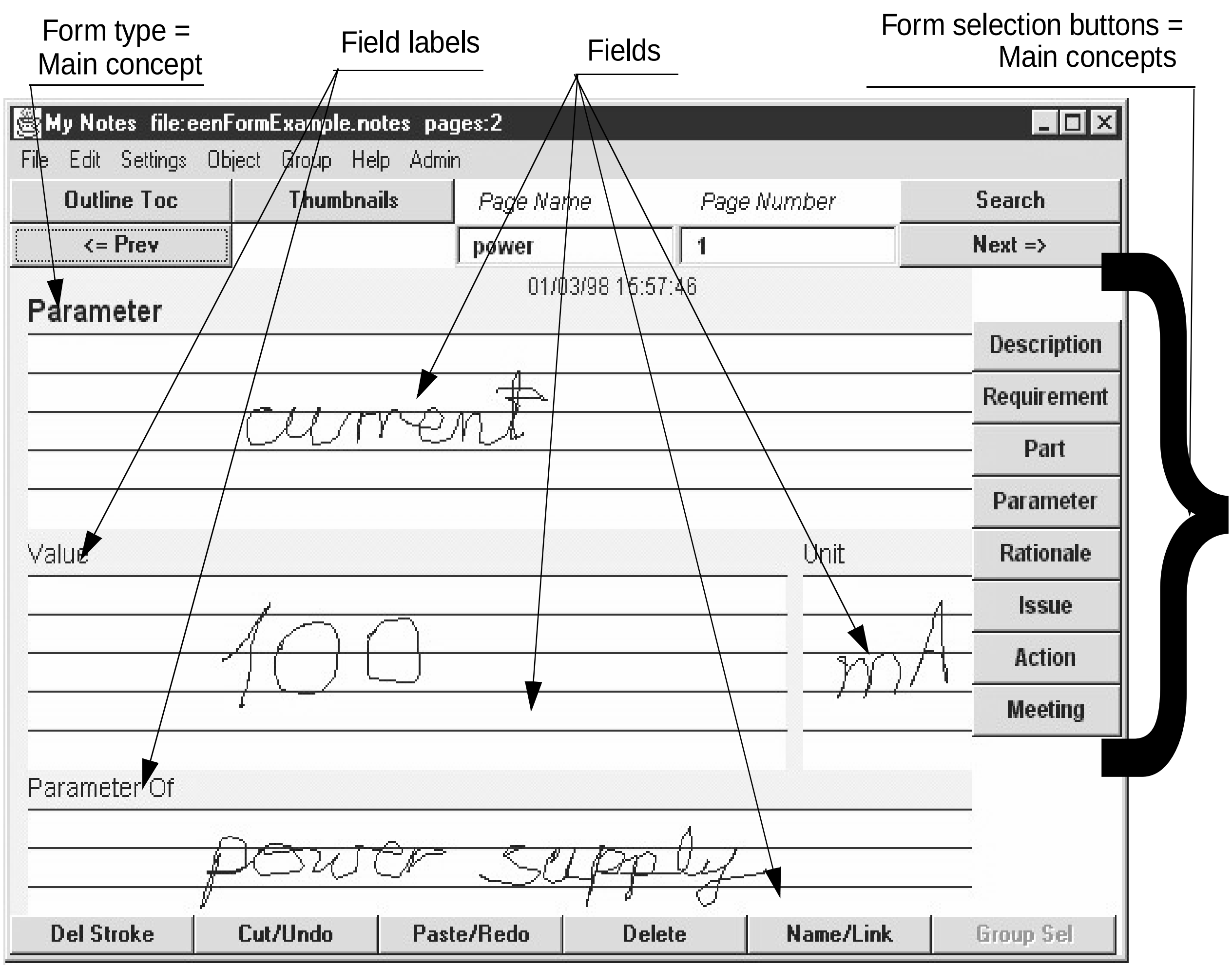
Figure 21. EEN with User-defined Labels (FFU)



6. EEN with Fixed-form Interface

The third interface variant (FORM, see Figure 22) is fixed-form, instead of free-form, and uses the same domain terminology as the FFP interface. Each of the main terminology concepts has a corresponding form with attributes and relations represented as fields. New pages with forms of desired type are created by tapping on a button on the right-hand side of screen. Any number of forms of each type (i.e. any number of main concepts) can be used. A special general type form, called "Description", is provided for situations when users do not know how to classify information. Mechanisms for browsing and retrieval of forms are the same as described in Section 4.

Figure 22. EEN with Fixed-form Interface (FORM)



7. Semantic Labels

Semantic labels attached to engineer's notes make their meaning explicit to the computer system. The mechanism for adding labels was described in Section 3. This section describes the terminology used for labels. The terminology is based on formal engineering representations.

7.1 Formal engineering ontologies

In order to make design information effectively accessible to engineers, it needs to be classified, and related using a well-defined terminology. Engineering ontologies are used for this purpose. An ontology is a formal description of objects[1] from a given domain with their properties, relationships, and behaviours; it provides a representation of domain knowledge.

A set of formal engineering ontologies has been developed in the Enterprise Integration Laboratory (EIL) at the University of Toronto. The ontologies include requirements ontology [Lin et al. 1996], product ontology [Lin 1997], organization ontology [Fox et al. 1996], cost ontology [Tham et al. 1994], quality ontology [Kim et al. 1994], activity [Gruninger et al. 1994] and resource ontology [Fadel et al. 1994], and project ontology [Gwizdka et al. 1996]. In the EEN we used elements from requirements ontology, product ontology, and project ontology.

Our motivation for using engineering ontologies as the basis for terminology used in EEN was to provide terminology for engineering design that is familiar to engineers and that can be shared by them. We chose ontologies from EIL, because they provide appropriate terminology for structuring engineering notes, that is, these ontologies can answer a set of questions that engineer's notes should answer. For example: What are the subcomponents of a part? What is the value of the parameter-X in part-Y? What are the requirements of a part?

1. In the context of representations, object is used interchangeably with concept.

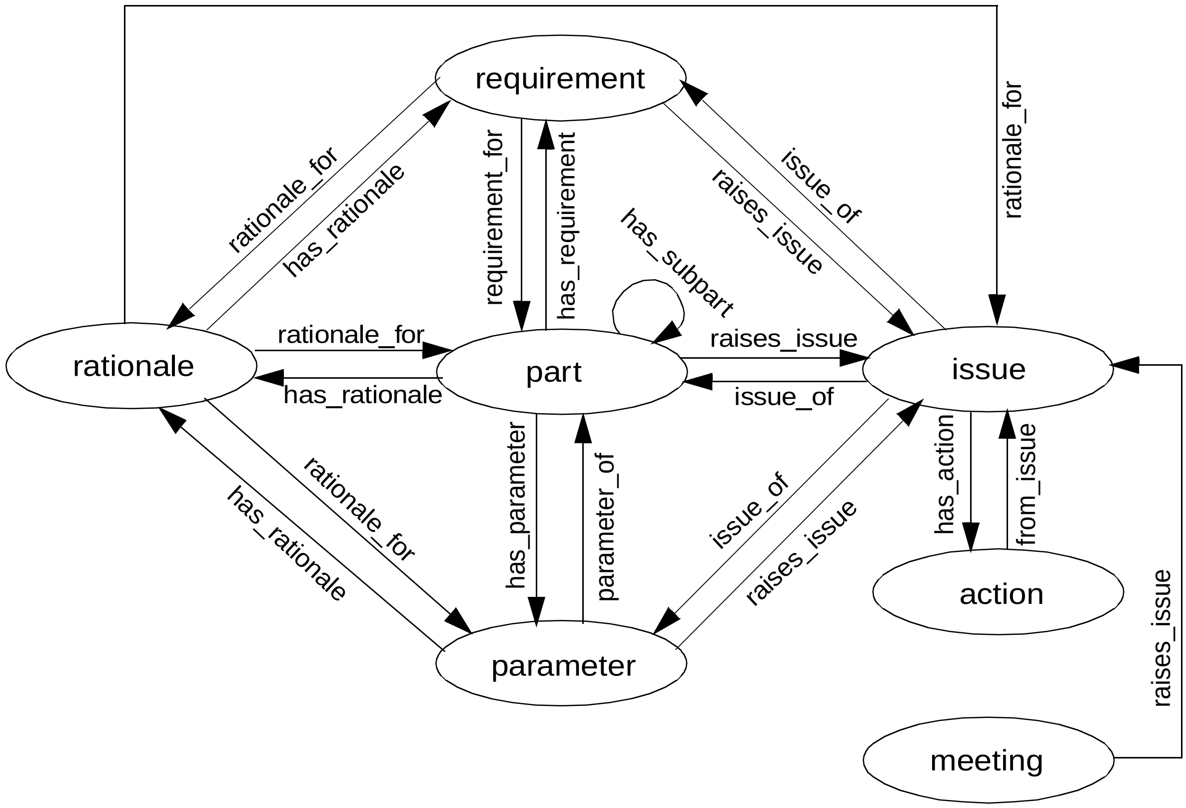
Table 2: Subset of ontologies used in the EEN

Main concept	Attributes	Relations
Requirement	name, description, expression, status	requirement_of, has_rationale, raises_issue
Rationale	name, description	rationale_for
Part	name, description, type	has_requirement, has_subpart, subpart_of, has_parameter, has_rationale, raises_issue
Parameter	name, description, unit, value, physical dimension	parameter_of, has_rationale, raises_issue
Issue	name, description, status	issue_of, has_action, solved_by
Action	name, description, status, due date	from_issue, raises_issue
Meeting	name, description, date	raises_issue

7.2 Subset of ontologies employed in the EEN

The terminology elements used in the EEN were selected from the product, requirement, and project management ontologies for the purpose of capturing a simple design meeting. Table 2 lists ontology elements used in the EEN with their attributes and relations. Only a subset of ontologies were used. Furthermore, not all attributes and relations from ontologies have been used, while some others have been modified. For example, only one level of requirements are allowed. Relations between ontology elements are shown in Figure 23.

Figure 23. Relationships of the design process, product, and project ontologies

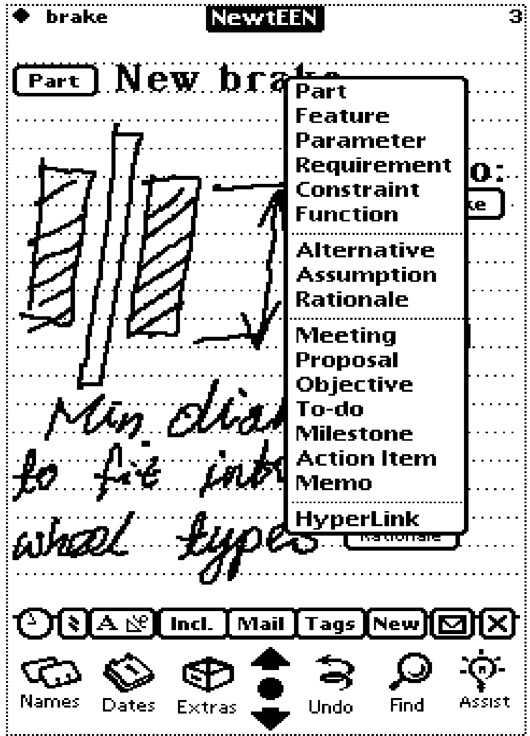


8. Implementation

In the course of this research we have implemented two versions of the EEN. The first on the Apple Newton MessagePad™ hardware, and the second in Java™. Although the implementations had many elements in common, the details of the design described in this chapter refer to the Java version.

The “Newton” version was written in Newton Script and run under Newton Operation System version 1.3 or lower on MessagePad™ models 100-120. User interface from this implementation is shown in Figure 24. The main limitation of Newton-based EEN was the small screen size which made it difficult to use in practice.

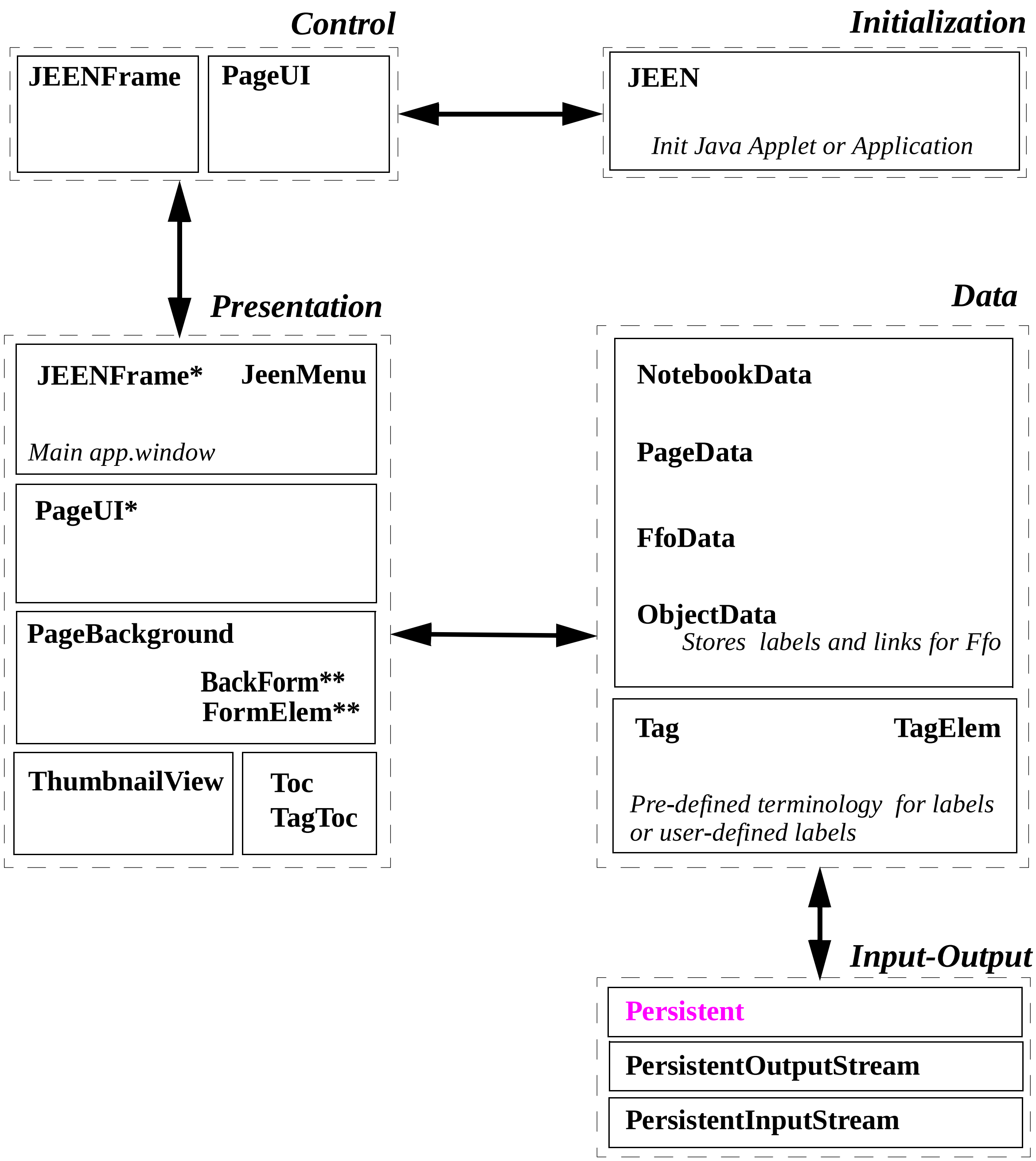
Figure 24. EEN user interface on the Newton



The Java implementation was written in Java 1.0.2; it consists of 33 Java classes and approximately 8500 lines of code (Figure 25 depicts internal architecture of the Java EEN). This version has the capability to run on any platform with a Java virtual machine[1] (JVM version 1.0.2[2]) and pen input[3]. Due to the relatively slow speed of execution of Java code by currently available Java virtual machines, the EEN requires computers with fast processors, for example, we used 266MHz Pentium-based computer with 64MB RAM. We used Wacom pen-tablet with a non-pressure sensitive pen (SP 200) as a pen-input device.

1. The EEN could be run by Java virtual machines provided in Web browsers (e.g. Netscape, Internet Explorer). However, due to security restrictions no access to local file system is possible, and thus, notes could not be stored.
2. Higher version of JVM can, in principle, execute the EEN. However, due to changes, and in particular due to the modifications in the event processing model, some functions may be not available.
3. The EEN can be used with mouse instead of a pen, however using a mouse for writing is very inconvenient.

Figure 25. Simplified internal architecture of the EEN



Legend:

Java Class

Java Class Interface

*** appears twice - class contains "presentaion" and "control" functionality**

**** used only in FORM interface**

9. Summary

The Electronic Engineering Notebook supports free-form (FFP and FFU) or fixed-form (FORM) interaction, and allows for semantic information structuring using either terminology based on formal engineering ontologies (FFP and FORM) or terminology defined by users (FFU). The main functions of the EEN are information capture, semantic information structuring, and information browsing and retrieval. In the free-form interface variants, semantic information structuring is performed by attaching labels to notes, in the fixed-form variant, structuring is performed by using appropriate forms and writing notes in fields with pre-attached, fixed labels. The EEN provides four main methods of information access: sequential access, page name access, semantic index access and semantic linking. In addition, the EEN provides direct page number access and thumbnail views of pages. Initial implementation of the EEN run on the Apple Newton MessagePad™. The current implementation is in Java™.

Chapter 4

Experiment

“Experiment!
Make it your motto day and night.
Experiment,
And it will lead you to the light.”

Cole Porter, “Experiment” from “Nymph Errant”

“It is a good morning exercise for a research scientist to discard a pet hypothesis every day before breakfast. It keeps him young.“

Konrad Lorenz, “On Aggression”

1. Introduction

Electronic Engineering Notebook, described in detail in the previous chapter, allows for taking notes and structuring them. We conducted an experiment in which we compared free-form and form-based interface variants of EEN as alternatives for structuring design meeting notes. Free-form interface was compared in two variants, the first using domain-based labels for semantic indexing and the second using user-defined labels. We examined the usability of each user interface variant. The comparison was performed from the point of view of capturing, structuring, and subsequently retrieving design information, and more specifically, the design process record (requirements, rationale, issues), the product structure (parts, parameters, values), and project management items (actions, meetings). We compared ease of use of free-form versus form-based interface and ascertained suitability of pre-defined domain-based terminology versus user defined terminology.

2. Research Expectations and Hypotheses[1]

The experiments were designed to evaluate our research expectations and to test hypotheses in the area of note-taking, structuring notes, and information retrieval from notes. In some cases expectations refer to observations which cannot be quantified and thus corresponding hypotheses are not provided in these cases.

2.1 Note-taking

Expectation 1a

Note-taking in a free-form interface is easier than in a form-based interface.

1. For each of the hypotheses, the corresponding null hypotheses are that there are no differences concerning the examined effects.

Our expectation is that note-taking style afforded by a free-form interface is closer to note-taking on paper, and thus, that a free-form style interface is more natural, and therefore easier to use. We expect that a more natural free-form interface allows for quicker note-taking.

Expectation 1b

Free-form interface allows users to take and subsequently structure notes more quickly than a form-based interface.

Hypothesis 1a

Time taken to record notes and to structure them is shorter in the free-form interface than in the form-based interface.

We further expect that free-form interface, being easier to use, allows for taking better, that is more complete, notes, and thus:

Expectation 1c

Notes taken using the free-form interface are more complete

The completeness of notes can be measured by counting the number of concepts covered and comparing it to the number of concepts contained in the source from which the notes were taken.

Hypothesis 1b

The number of concepts captured in notes taken using the free-form interface is higher than when using the form-based interface

2.2 Structuring notes

Semantic structuring involves two steps: applying the structuring mechanism and deciding to which semantic category information belongs to. We expect that performing structuring and taking notes at the same time is difficult and, thus, that delaying structuring is beneficial.

Expectation 2a

Structuring notes is easier after, rather than during, note taking.

Selecting one's own categories imposes lesser cognitive load than selecting pre-defined categories. This effect is based on familiarity with terminology.

Expectation 2b

Performing semantic structuring employing user's own terminology is easier.

Experienced users are more familiar with the terms from their domain, and thus applying categorizations should be easier for them; they should be able to do it better in a sense of "conscious" categorization.

Expectation 2c

Domain experts can better apply semantic categories.

2.3 Information retrieval from notes

Similar effects of user-defined terminology and expert use should be observed during information retrieval from notes, and hence:

Expectation 3a

Information retrieval using one's own terminology is easier and more effective.

One of the ways to evaluate the effectiveness of search is to measure the number of categorization-based steps taken by users in searching for information.

Hypothesis 3a

The number of categorization-based search steps is smaller when using one's own terminology than when using pre-defined terminology.

Expert users should better employ categorizations. We can measure this skill by comparing the number of categorization-based search steps taken by users.

Expectation 3b

Experts can better use categorizations during information retrieval from notes

Hypothesis 3b

Number of categorization-based search steps is smaller for experts than for novices.

Based on more “conscious” usage of semantic categories (Expectation 2c), experts should employ categorization-based search more often than novices.

Hypothesis 3c

Experts use categorization-based search more often than novices.

3. Methodology

3.1 Subject population.

Twenty students (undergraduate and graduate) from the Department of Mechanical and Industrial Engineering at the University of Toronto participated in the experiment. Subjects were chosen on the basis of their engineering design experience. The minimum experience required was a university engineering design course.

Subjects were paid $20 for their participation in the experiment. Copies of the subject consent form and other documents related to experiment administration are provided in Appendix E.

3.2 Experimental design

3.2.1 Experiment conditions

1. Free-form interface with domain-based semantic labels (FFP).
2. Free-from interface with user defined labels (FFU).
3. Form-based interface with domain-based forms and fields, based on the same terminology in the first condition (FORM).

Table 3: Interface Conditions

		Terminology	
		Pre-defined terminology	**User defined terminology**
Interface type	**Free-form**	FFP	FFU
	Fixed-form	FORM	---

The interfaces used in the experiment are described in Chapter 3. The terminology is described in Chapter 3, Section 7.

Table 4: Allocation of expert and novice subjects across interface conditions

Interface Condition	Novice	Expert	Total
FFP	4	3	7
FFU	2	4	6
FORM	4	3	7
Total	10	10	20

Subjects were randomly allocated across the three interface conditions (Table 4). For the definitions of “expert” and “novice” see Section 5.3.

The experiment consisted of two sessions, each lasting approximately one hour. The sessions were conducted separately for each subject. In the first experimental session subjects performed a note taking task from a videotaped design meeting (design project used in the meeting is described in the next Section 3.2.2). In the second session they performed an information retrieval task. (Experiment sessions are described in detail in Section 3.2.3 and 3.2.4.)

3.2.2 Design Project

Design project was chosen to be simple and to use generally familiar concepts (e.g. length, rather than stiction torque; case, rather than shoulder yaw joint). The objective of the project was to design a programmable thermostat interface for a house heating system. The interface was to allow programming of a temperature profile for one day (for example, 18 C during the night, 22 C from 7:00 am till 8:00 am, 15 C during the day, 22 C 6:00 pm till 11:30 pm).

Design session

The videotaped design meeting was performed by a design team composed of two “designers” involving a university professor and a graduate student as actors. The meeting lasted 10 minutes. Topics discussed during the meeting included: components of the interface, along with their parameters and values (e.g. function keys, size 1cm x 1cm); requirements of and rationale for these components and their parameters (e.g. rationale for the size of the keys: adult finger size); actions required by the project and subsequent meetings scheduled (e.g. preparation of layout of the keys, due in a week). A list of concepts to be discussed during the design meeting was prepared in advance (the list is provided below).

1. Thermostat control

    1.1 Parameter: programmable for 24 hour period of time

    1.2 Rationale: people’s activities repeat daily

    1.3 Parameter: programmable temperature range 10-35 degrees Centigrade

1.4 Rationale: bottom limit - interior house equipment not damaged because of low temperature, upper limit - average human body temperature

2. Placement of the thermostat interface
   2.1 Parameter value: 1.2 m above the floor level
   2.2 Rationale: higher than a little kid could reach, and not too high for an average adult
3. Part: Numeric keypad
4. Part: Function keys
   4.1 Number of keys: 3
   4.2 Parameter value: size of keys 1cm x 1cm
   4.3 Rationale for size: big enough for a finger; not too big to save space and material
5. Part: LCD display
   5.1 alphanumeric 6x15 digits, auto backlit (green) at night
6. Part: Case
   6.1 Parameter: material; Value: plastic or alternatively metal
   6.2 Rationale for material: durability
   6.3 Parameter: colour: Values: available in a variety of gray/beige/white/black.
   6.4 Parameter value: height: 10cm
   6.5 Parameter value: width: 12cm
   6.6 Parameter value: depth: 2cm
   6.7 Rationale for depth: to fit power supply

7. Part: Power supply

    7.1 Parameter values: current min. value 50mA, desired 100mA

8. Part: Back-up battery

    8.1 Parameter value: a 9V alkaline battery

    8.2 Rationale: in case of power outage the temperature setting cannot be lost

9. Action: design sequence of keystrokes to enter the data, due in a week

10. Action: analyze cost of parts, due in two weeks

11. Next meeting scheduled in two weeks

A diagram illustrating relations among all concepts is provided in Appendix B.

3.2.3 Note-taking session

The first session started with a short (10-15 minutes) training. The purpose of the training was to give subjects a short background on the design process and its terminology, to explain the task, to demonstrate the system interface, and, in the FFP and FORM conditions, to familiarize users with the domain terminology usage in the interface. At the end of the training, subjects spent several minutes getting used to the electronic pen and to the user interface.

In the main part of the session, subjects spent about 20-45 minutes (depending on the experiment condition) taking notes while watching a video from the design meeting. Subjects were asked to take notes as if they were an absent member of the design team. Description of the task and other handouts given to the subjects are collected in Appendix C.

Subjects were allowed to control the video, they could rewind it, or pause it for a reasonable amount of time when they wished.

After watching the video, subjects in the free-form conditions (FFP and FFU) were asked to structure their notes by adding labels. In FFP condition subjects could further structure the notes by adding attributes and relations to the labelled objects. Subjects in the FORM condition were asked to actively review their notes by going through them and counting the types of forms used.

At the end of the session subjects were debriefed and a short (5 minutes) interview was conducted. The purpose of debriefing was to find out subjects' experience with the notebook interface. In the interview, subjects were asked about their note-taking habits (see Appendix D for interview questions).

3.2.4 Information retrieval session

The information retrieval session was run for each subject several days after the first session. During the second session subjects were asked to find information in their notes.

Subjects were presented with a list of sixteen questions covering all important concepts from the design meeting (for a list of all concepts and for a graphical representation of their relations please see Appendix B). Subjects were asked not to answer the questions directly, but to find answers in their notes and to talk out loud describing steps they were taking to locate information. The table of contents with indexes of categories and page names were shown to subjects again. Subjects were asked to use the structural elements in information retrieval. Subjects were also asked to start each search anew. We examined subjects' information finding strategies and the existence of the required information in subjects' notes.

At the end of the session subjects were debriefed. During debriefing subjects were asked to further explain, if necessary, their information retrieval strategies and to describe their experience with notes retrieval.

Session two was recorded on an audio tape.

4. Apparatus

The two main components of experimental apparatus were hardware and software.

Hardware: A 266MHz pentium-based desktop PC (IBM Aptiva) with 64MB RAM running Windows'95 and equipped with a Wacom pen tablet as an input device.

Software: The EEN JAVA application described in Chapter 3.

Experiment location. Experiment was conducted in the Interactive Media Laboratory at the Department of Mechanical and Industrial Engineering at the University of Toronto.

5. Data Collection and Evaluation

5.1 Data Collection

The following data was collected in the experiment: notes taken by subjects during the first session, notes made by the experimenter on observations of subjects and during debriefing in both sessions, subject answers to interview questions, and audio tapes from the second session. Experimenter notes from the second session included a record of the steps taken by subjects in retrieving information to answer questions.

5.2 Data Evaluation

Collected data was evaluated in the following areas:

1. Subjects' notes statistics

   The main statistics were calculated automatically by the note-taking program (EEN). These included: number of pages (total and full), number and type of labels (or forms and fields), number of labels per page, number of *main concepts*, and number of *main concepts* per page. In the FORM condition main concepts are equivalent to forms, in the FFU condition main concepts are the same as user labels, and in the FFP condition main concepts are the seven main pre-defined labels (see Chapter 3, Section 7.). In the FFP and the FORM conditions numbers of attributes and relations were also calculated (total, per page, and per main concept). In addition, terminology employed by subjects for labels in the FFU condition was analyzed according to the domain terminology used in the FFP and the FORM conditions. To explore patterns in terminology usage, user terms were divided into abstract and concrete groups.

Additional statistics were performed manually by going through all subjects' notes. These included statistics of note organization elements used by subjects. For example, usage of indents, bullets, lines, arrows, and braces.

2. Note-taking session statistics

We measured time taken by subjects to write notes while watching the video and time taken to organize notes afterwards. In the FORM condition the first time includes both note-taking and organization.

3. Information retrieval session statistics

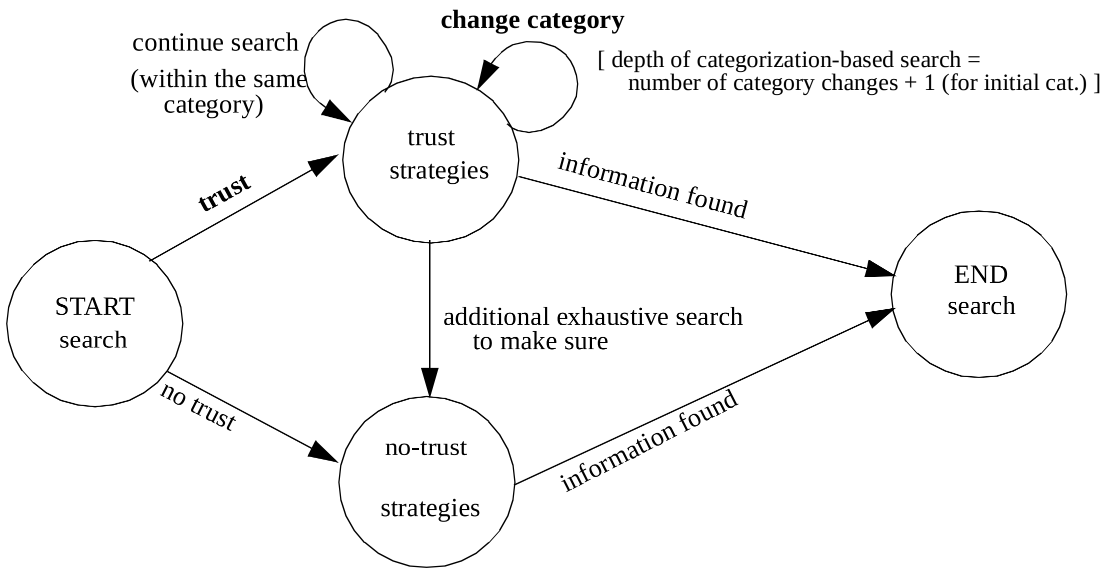
In the retrieval session subjects were finding information in their notes to answer sixteen questions covering main concepts from the design session. Completeness of subjects' notes was measured by counting the number of concepts covered in notes. In addition, the number of concepts covered that were categorized was measured. A score equal to the number of concepts involved in an answer was assigned to each question. Answers not covering all concepts were given partial scores.

4. Information retrieval strategies

Notes from the second session, and from audio tapes, were analyzed with regard to the strategies employed by subjects to find information in their notes.

We divided information finding strategies into two main groups: "trust strategies" and "no-trust strategies". Trust strategies were employed when subjects applied categorizations during note-taking session and trusted their own categorizations in the retrieval session. We refer to trust strategies also as categorization-based search strategies. We call other strategies used by subjects “no-trust strategies”. Trust strategies included all methods in which search was performed using categorizations. No-trust strategies included flipping through pages, random jumping to pages, or jumping to the main page.

Figure 26. State diagram of the search cycle



We measured the depth of search when using categories. The depth of search was defined as the number of different categories explored in the information finding process. Categories searched again after searching another category were counted twice.

5. Note-taking habits

Answers to the short interview conducted after the first session were analyzed to gain background information on types of note-taking habits. For example, on the types of note reorganization (e.g. rewriting, summarizing).

Variables used to denote dependent measures from the first four areas are grouped in Table 5. For the detailed experiment results please refer to the tables provided in Appendix F.

5.3 Independent measures

The results were analyzed with respect to two independent factors:

1. COND - Interface condition (FFP, FFU, and FORM)

   We analyzed the effects of interface condition making comparisons along two dimensions: free-form versus form-based interface, and pre-defined, domain-based terminology versus user defined terminology.

2. EXPERIEN - Subjects' engineering experience.

   We defined expert subjects as students who had additional engineering design experience gained either by work in industry or while performing university research beyond the standard design courses. Classifying subjects as experts and novices was based on the information given by subjects as a response to the interview questions (see Appendix D).

5.4 Dependent measures

We defined a range of dependent variables measuring different aspects of note-taking, note-structuring and information retrieval from notes. Some of the measures were used in confirmatory analyses to evaluate the testable hypotheses (e.g. CONT - Hypothesis 1b, TAGSEDEP - Hypothesis 3a and Hypothesis 3b, TRUSTR - Hypothesis 3c), other in exploratory analyses. Values of the dependent measures were found in the process of data evaluation described in Section 5.2.

Table 5: Definitions of dependent measures

#[a]	Measure Name	Definition
1	PAGES	Total number of pages with notes (i.e. excluding empty pages)
	TOTTAGS	Total number of labels or fields used.
	SEPTAGS	Total number of separate labels or fields. In FFP and FFU it is equal to the number of objects with at least one label attached; in FORM it is the number of fields used. (the same as TOTTAGS for FFU and FORM and different only for FFP)
	TAGSPAGE	Number of labels or fields per page
	MTAGPAGE	Main concept labels per page (in FORM it is the quotient of “typed” forms to all forms, in FFU it is equal to TAGSPAGE).
	ATTR	Number of attributes used (FFP and FORM only)
	ATTRPAGE, ATTRMTAG	Number of attributes used, respectively, per page and per main concept (FFP and FORM only)
	REL	Number of relations used (FFP and FORM only)
	RELPAGE, RELMTAG	Number of relations used, respectively, per page and per main concept (FFP and FORM only)
2	TTOTAL	Total time taken to write and organize notes
	TNOTE	Time taken to write notes (in FORM it includes notes organization and is equal to TTOTAL)
	TORG	Time taken to organize notes (by definition equal to zero in FORM)
3	CONT	Number of design meeting concepts covered in notes
	STR	Number of categorized design meeting concepts covered in notes, that is concepts marked separately by using structuring elements (labels or fields)
4	TAGSEDEP	Depth of search using structuring elements (labels, form types or fields). It is calculated as the number of different categories (terms) used during a search.
	TRUSTR	Number of “trust” strategies used. “Trust” strategies are information finding strategies that employ categorizations, for example, search for labels.
	NTRUSTR	Number of “no-trust” strategies used. “No-trust” strategies are information finding strategies that do not employ categorizations, for example, flipping through pages.

a. Data evaluation areas (1- notes statistics, 2- note-taking session statistics, 3- Information retrieval session statistics, 4- Information retrieval statistics) as described in Section 5.2.

6. Quantitative Analysis of Results

We performed both qualitative and quantitative analyses of the experiment results. The quantitative analysis and its results are described in this section. The qualitative analysis of our observations and interviews with subjects is presented along with discussion in Section 7..

6.1 Effect of three user interface conditions and subjects' experience

Multivariate analysis was carried out using three user interface conditions and experience as the factors with PAGES, CONT, STR, TOTTAGS, SEPTAGS, TAGSPAGE, MTAGPAGE, TTOTAL, TAGSEDEP, TRUSTR and NTRUSTR as the dependent variables. The multivariate effect of user interface was significant, as assessed by Wilks' Lambda ($F(10,16)=9.22$, $p<0.0001$). The multivariate effect of experience was also significant ($F(5,8)=4.2$, $p<0.05$). Separate univariate analyses were then carried out to determine the source of these effects. User interface condition was found to have significant univariate effects on: PAGES ($F(2,12)=7.98$, $p<0.01$), on CONT ($F(2,12)=5.66$, $p<0.05$), and on SEPTAGS ($F(2,12)=8.32$, $p<0.01$). Experience was found to have significant univariate effects on TRUSTR ($F(2,12)=5$, $p<0.05$). The effects of user interface and experience are discussed in the two following sections (Section 6.1.1 and Section 6.1.2, respectively).

6.1.1 Effects of three user interface conditions

Hypothesis testing: Hypothesis 1b

Table 6 summarizes the means across the interface conditions for each of the statistically significant dependent variables. As can be seen in Table 6 (also Figure 27), the level of CONT is higher in condition FFP than in the other two conditions, and thus notes of subjects in FFP condition provided the best coverage of concepts discussed in the design meeting. We can attribute this result to

Table 6: Effect of the three interface conditions

Interface condition	Number of pages (PAGES)	Number of labels or fields (SEPTAGS)	Concept coverage (CONT)
FFP	11.14	22.67	93%
FFU	6.80	14.00	78%
FORM	17.71	40.00	73%
Mean	12.42	25.38	82%

more natural note-taking in a free-form interface. However, the level of CONT in the second free-form condition (FFU) is lower than in FFP[1], and not much higher than in FORM condition. The explanation may lie in the coincidental differences in note-taking habits between subjects in FFP and FFU conditions. This explanation is partially supported by the number of pages with notes. Subjects in FFP condition created almost twice as many pages as subjects in FFU condition, and thus FFP subjects might have been more careful note-takers. We can also note that while subjects in FFU condition created the smallest number of pages, the coverage of meeting concepts in their notes was higher than in FORM condition notes. Thus, the efficiency[2] of note-taking in free-form conditions was higher than in FORM condition. These results confirm Hypothesis 1b[3] and thus Expectation 1c.

1. It should be noted that in the free-form conditions CONT measures the contents of notes before the structuring is applied, and, thus, terminology does not affect it.
2. Efficiency is defined here as number of concepts covered divided by the number of pages created
3. Accepting a hypothesis means that an associated null hypothesis has been rejected.

Figure 27. Coverage of meeting concepts in three interface conditions (CONT)

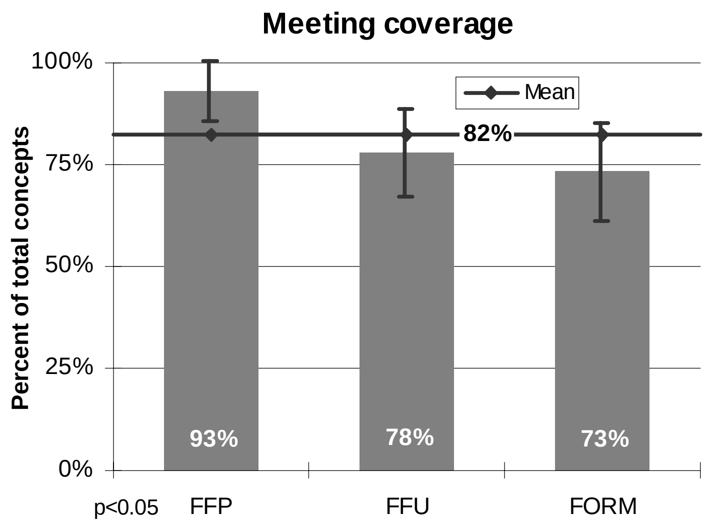
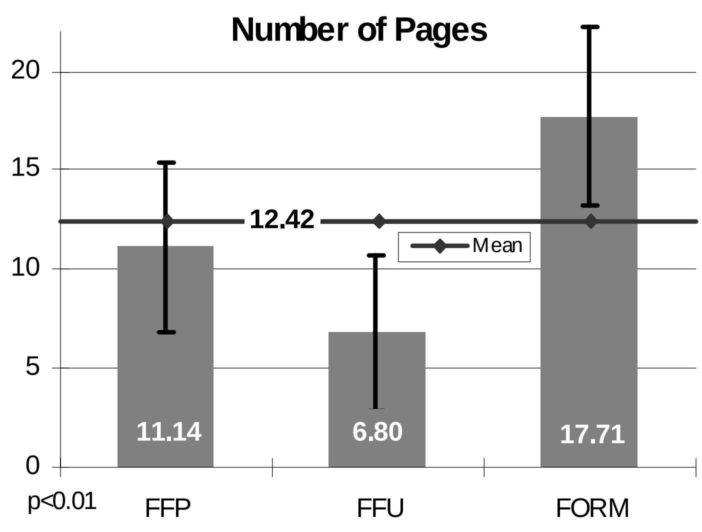


Figure 28. Number of pages (PAGES)



Hypothesis testing: Hypothesis 1a

None of the considered independent factors (interface condition F<1.5 and subjects' experience F<1) had significant effect on the total time. Hence, we cannot state which interface was the fastest to take notes. The higher level of TTOTAL in FFP condition might have been a result of subjects note-taking habits. Therefore, the null hypothesis corresponding to Hypothesis 1a cannot be rejected on the basis of the experimental evidence.

Figure 29. Total time (TTOTAL)

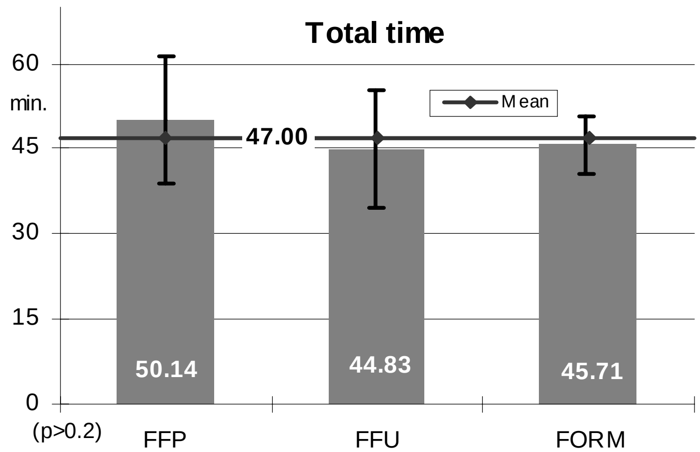
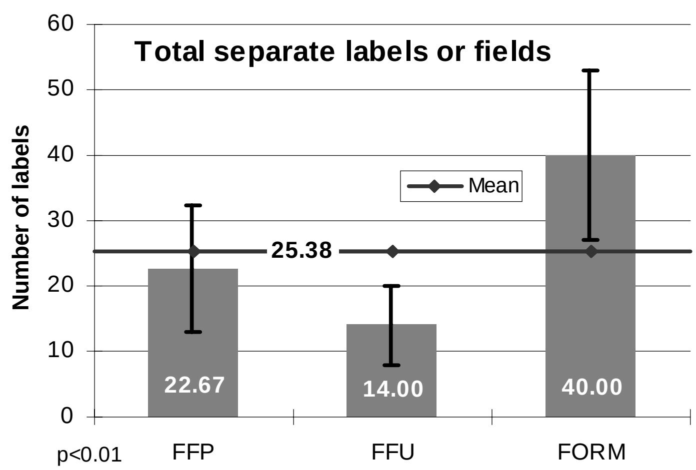


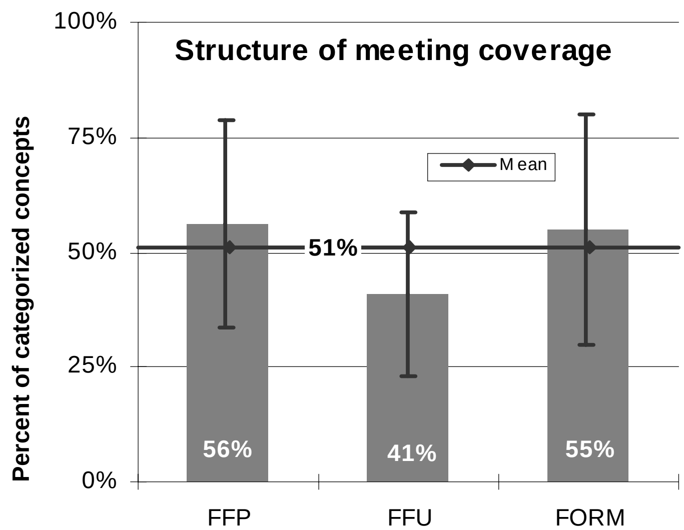
Figure 30. Number of separate structural elements (SEPTAGS)



Exploratory analysis:

We compared the total number of separate labels or fields (SEPTAGS) (Figure 30) with the number of structural elements in meeting coverage (STR) (Figure 31), denoting how many concepts covered in notes were separately categorized. (The interface conditions did not have statistically significant effect on the latter.) We can see that the level of STR is similar in the FFP and FORM conditions, while SEPTAGS in the FORM condition is about two times higher than in the FFP condition. In the FFU condition, both the level of STR and of SEPTAGS were lower than in the FFP condition. This indicates that the structure imposed on the notes taken using FORM interface was much more detailed. This structure was, perhaps, too detailed and contained many “unnecessary” elements, since it did not increase the level of STR (see also discussion in Section 7.1.3).

Figure 31. Number of structural elements in meeting coverage (STR)



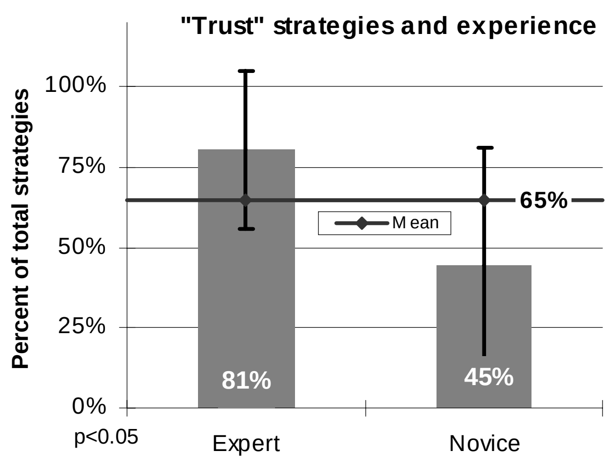
6.1.2 Effect of subjects' experience

Figure 32 summarizes the means across the levels of experience for TRUSTR. (for a description of "trust" strategies see Section 5.2).

Hypothesis testing: Hypothesis 3c

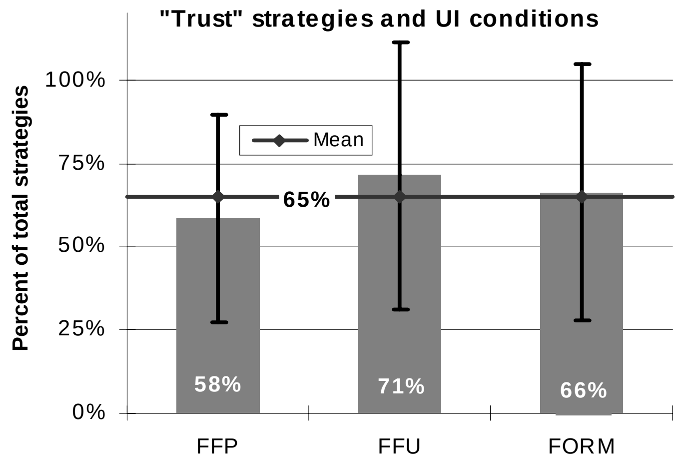
As can be seen in Figure 32, the level of TRUSTR is lower for novices than for experts. Thus expert subjects used categorizations in information retrieval more often than novices. This indicates a higher degree of trust in expert's own information classification and a better understanding of terminology used for categorizations. These results confirm Hypothesis 3c and thus, in part, Expectation 3b.

Figure 32. "Trust" strategies (TRUSTR)



The interface condition factor was not found to have a significant effect on TRUSTR, the means across interface conditions are presented in Figure 33.

Figure 33. "Trust" strategies across interface conditions (TRUSTR)



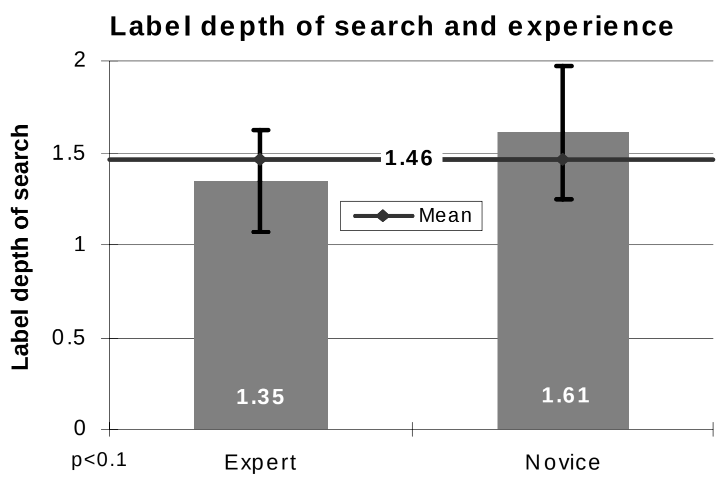
6.2 Effect of terminology and subjects' experience

To assess the effect of pre-defined, domain-based, terminology (FFP and FORM) versus user defined terminology (FFU) a separate multivariate analysis was carried out using the interface conditions, in which the observations from FFP and FORM conditions were grouped together (COND), and using experience (EXPERIEN) as the factors with PAGES, CONT, STR, TOT-TAGS, SEPTAGS, TAGSPAGE, MTAGPAGE, TTOTAL, TAGSEDEP, as the dependent variables. The effect of user interface was similar as discussed in Section 6.1. The multivariate effect of experience was found to be significant, as assessed by Wilks' Lambda ($F(4,12)=10.8841$, $p<0.01$). Separate univariate analyses were then carried out to determine the source of these effects. Experience was found to have borderline significant univariate effects on TAGSEDEP ($F(1,15)=3.21$, $p<0.1$). In the first analysis, in which all three interface conditions were separate (see Section 6.1), effect of experience on TAGSEDEP did not qualify as significant ($F(2,12)=3.02$, $p>0.1$). The effect of experience was thus most probably amplified by the effect of pre-defined and user defined terminologies. However, no significant effect of terminology type on TAGSEDEP was found.

Hypothesis testing: Hypothesis 3b (indirectly again **Expectation 2c**)

Figure 34 shows the means across the levels of experience for the dependent variable TAGSEDEP. As can be seen in Figure 34, the level of TAGSEDEP is higher for novices than for experts. Expert subjects were able to find information using the categorizations quicker than novices. This indicates, similarly as in discussion of TRUSTR (see page 61), that experts better understand the terminology used for categorizations and are thus able to efficiently apply categorizations in a consistent manner. These results confirm Hypothesis 3b and, thus, in part, Expectation 3b. We can interpret better usage of categories by experts during information retrieval to indicate their ability to better apply categories during structuring phase (Expectation 2c).

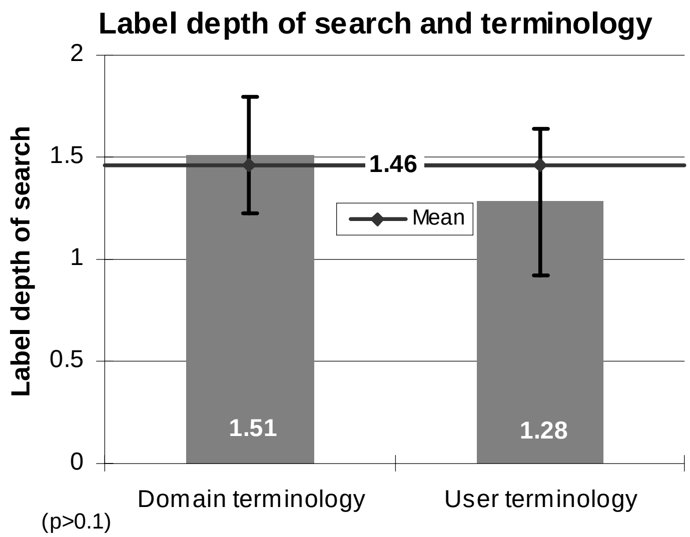
Figure 34. Label depth of search and experience (TAGSEDEP)



Hypothesis testing: Hypothesis 3a

Figure 35 shows the means across the terminology types for the dependent variable TAGSEDEP). No significant effect of terminology type was found on TAGSEDEP (F(1,15)=1.82, p>0.1). Therefore, the null hypothesis corresponding to Hypothesis 3a cannot be rejected on the basis of the experimental evidence.

Figure 35. Label depth of search and terminology type (TAGSEDEP)



6.3 Effect of FFP versus FORM interface

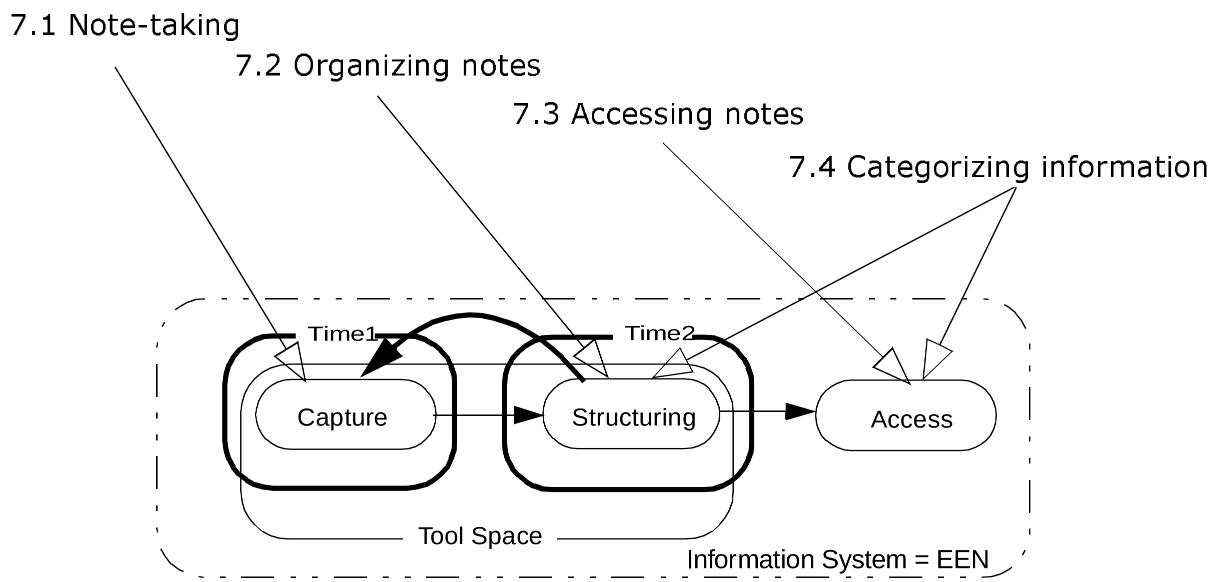
Exploratory analysis:

Both the FFP and FORM interface conditions employed attributes and relations as additional structuring elements that were absent in FFU condition. A multivariate analysis carried out using the two interface conditions (FFP and FORM) as the factors with ATTR, ATTRPAGE, ATTRMTAG, REL, RELPAGE, RELTAG, as the dependent variables. The multivariate effect of the two user interface conditions was significant, as assessed by Wilks' Lambda ($F(6,4)=22.21$, $p<0.005$). Separate univariate analyses were then carried out to determine the source of these effects. User interface condition was found to have significant univariate effects on: ATTR ($F(1,9)=28.4$, $p<0.001$), on ATTRPAGE ($F(1,9)=22.56$, $p<0.05$), and on ATTRMTAG ($F(1,9)=50.05$, $p<0.0005$). No significant effect on relation variables was found. These effects are discussed in Section 7.4.5, and the results presented in Figure 38 and Figure 39.

7. Qualitative Analysis of Results and Discussion

The discussion of qualitative experiment results is organized according to activities in note-taking process: note-taking itself, post-organizing notes, and accessing notes. Due to their significance, issues concerning information categorization, during and after note-taking, are grouped together and discussed in Section 7.4.

Figure 36. Organization of qualitative analysis section[1]



7.1 Note-taking

7.1.1 Sequential versus thematic note-taking

We can make a distinction between two different note-taking strategies: *sequential* and *thematic*. In the sequential strategy notes are taken in a sequence according to the order of information presentation. In the thematic strategy notes are taken by topics. Thematic note-taking strategy implies that notes are grouped according to topics during the note-taking process. EEN, our notebook pro-

1. Text and symbology used in this figure is introduced in Chapter 2.

gram used in the experiment (see Section 4.), allows for two styles of input, free-form input, in the FFP and FFU user interface variants, and structured input, in the FORM user interface variant. The first input style does not limit, or impose, any particular note-taking strategy, while the second strongly favours thematic note-taking.

We observed that the sequential note-taking is more natural than the thematic note-taking. Most experiment participants took their notes in a sequential manner. We observed this not only in the two free-form conditions (12 out of 13 in the free-form conditions), but also in FORM condition. An exception in the free-form conditions was participant FFU3, who was flipping pages back to add related information to the appropriate place in his notes. A number of FFP and FFU subjects were opening a new page for a new topic. However, they did not go back to a previous page if the topic was already mentioned and, in effect, they were taking notes sequentially.

Many subjects in the FORM condition wrote notes on a form that just happened to be opened. They did it quite often using “wrong” fields. This was especially the case with “less important” information. (Perceiving information as “important” plays a significant role in note-taking behaviour - see Section 7.1.5 for discussion). Some subjects put many notes into one field on a form. In contrast, others put notes related to the same topic on several forms. From analysis of FORM subjects’ notes, we found that subjects added more information only on 15% of pages, whilst all notes on the remaining 85% pages were created sequentially. Although the FORM interface strongly favours thematic note-taking, most of the subjects were not able to follow this strategy and, in effect, took notes in a sequential manner not using properly the fields provided by the forms.

7.1.2 Marking notes

Marking notes with additional graphical signs was very common. We observed that 12 out of 13 subjects in the free-form condition used some type of graphical marks (arrows, lines, braces) in the notes taken during the experiment. Some people developed their own language of note markings. For example, subject FFP6 used special double arrows to mark high level bullet points. Graphical marks offered cues allowing for visual locating of important points and of related information, and support perception of the note structure. During our interview after the first experiment session, subjects confirmed the use of special signs in their everyday notes.

FORM interface effectively prevented, or at least made it very difficult for subjects to use graphical elements to mark their notes. Almost all FORM-condition subjects complained about being limited by fields in a sense of space. In the FORM-condition only 3 out of 5 subjects used graphical marks, usually only inside fields. Subject FORM1, who used some limited marks, noticed that separated fields in forms prevented him from drawing lines among related items, instead he adopted a new note-taking strategy in which related information was put in the same order in two consecutive fields within the same form. During the retrieval session he had to remind himself about the new strategy, it was not as obvious to him as his usage of graphical marks. Subject FORM7 was the only one who marked notes crossing the field borders, for example, by circling notes outside of the borders.

7.1.3 Breaking down notes layout

Layout of notes is used similarly to marks described in the previous section - it helps to visually perceive the structure of notes. For example, nine out of thirteen free-form condition subjects used indents in their notes. Form-style interface by definition breaks down the personal layout of notes and enforces one of its own. This may be only a minor inconvenience gradually disappearing as a result of becoming familiar with the new layout. In our experiment, however, several FORM-condition subjects complained about notes being “too much broken apart”, which led to creating twice as many pages as in the free-form conditions. These observations were also confirmed by significant effects of interface conditions on number of pages and labels per page (see Section 6.1). Furthermore, four out of seven FORM subjects stressed their preference for taking notes on one page (for a short meeting like the one in the experiment), which would contain structure of notes in page layout.

7.1.4 Drawings

Drawings play an important role in engineering design [Ullman et al. 1990]. In our experiment, nine out of thirteen subjects in the free-form conditions made drawings, while only two out of five FORM subjects used them. After the second session, subject FORM5, admitted the helpful role of terminology (see Section 7.4.7) stressing at the same time, that forms prevented him from drawing. Drawing, similarly as graphical marking (see Section 7.1.2), was made difficult by the FORM interface.

Observations discussed in the above four sections point out the difficulties in note-taking when using FORM interface and confirm Expectation 1a.

7.1.5 Perspectives of receiving information

Qualifying received information as “important” plays a significant role in note-taking behaviour. From our observations and interviews with subjects we noticed four different perspectives on importance of information: professional, individual-subjective, project, and task at hand. In the first, we observed a mechanical engineering student not taking any notes on parts related to an electrical subsystem (although all subjects were equally told that the whole product structure is of their interest). In the second, we observed subjects taking less (or none at all) notes on colours. They explained later that colours are, in their opinion, not an important feature of this design. In the third, one subject took less detailed notes on open issues needed to be discussed at the next meeting; this subjects took detailed notes on already decided design features. He explained later, that the open issues should be discussed in detail at the next meeting, and that all the particulars given now are not important. In the fourth, we observed three subjects taking particularly detailed notes on all design elements related to their tasks.

Presentation of information additionally affects the subjective perception of importance. Subjects expected that important information was stressed in presentation and used this type of cue to start taking notes on new pages.

Similarly to deciding on information importance, subjects were judging how obvious a piece of information was. We observed, that rationale for requirements, parts, or parameters discussed in the design meeting were recorded or not depending how obvious it appeared to be. For example, size of an adult finger, given as a rationale for the key size, was often not written down. In the interview after the second session, subjects explained that it was too obvious to them.

Subjects' perspective influences also their interpretation of the terminology. For example, one of the subjects interpreted "requirement" not from the design project perspective, but from his own perspective, understanding it as "actions required from me".

Due to subjective interpretation of information by subjects there was no one correct categorization of the design meeting concepts. Therefore in the evaluation of structure of covered concepts (Section 5.2) in most cases we could only check if the concepts were marked separately, not if they were marked using a correct term.

7.2 Organizing notes after note-taking

In Section 7.1.1 we stated that sequential note-taking was more natural for experiment subjects. On the other hand, after taking notes we observed that participant FFP6 moved notes between pages by cut and paste trying to group related information on each page. Subject FORM7 created a summary in point form after his "regular" notes from the design meeting. From our interview we can anticipate that more subjects would have undertaken similar actions had they been more familiar with the EEN interface. This is further confirmed by rewriting practices mentioned in the interviews by nine out of twenty subjects. Subjects rewrite notes to regroup related information and to summarize notes. This indicates preference, at least by some subjects, for thematic organization of notes for information retrieval. To accommodate this preference, a free-form version of the EEN could support automatic regrouping of notes after their interactive structuring. However, process of rewriting notes serves also two other purposes. Three out of twenty subjects mentioned their strong preference for "neat" notes; one of them stressed that he rewrites "to clean up the notes and make them look neater". Other subjects noticed that the rewriting process helps them sort out the information and that they learn by doing it. Thus, the process of rewriting notes and regrouping information is important by itself and cannot be simply replaced by an automated procedure. Nevertheless, all the individual differences in note-taking habits indicate that offering automatic regrouping as an option would be useful to some people.

7.3 Accessing notes

7.3.1 Structure information embedded in layout

As already mentioned in Section 7.1.3 layout of notes contains information about their structure that is used to support finding information. Three out of seven subjects in the FORM-condition pointed out the role of their notes' format. The format contains embedded structural information (see [Moran et al. 1995]) that is used to locate information during visual scanning of notes. The pre-defined form interface enforces its own structure. This was perceived by subjects as obstacle. Two out of seven FORM condition subjects suggested user modifiable forms, with the possibility of designing own fields and using own terms.

In a short note-taking experiment we were not able to see how users adopt to fixed-forms after using them for a longer time.

7.3.2 Event-based information

People remember events that take place in their environment. These events may later provide subtle cues facilitating access to information. Event-based information gives a powerful way of complementing access to personal information (i.e. information that was once known to users and that may be associated with events from their personal lives) (see [Lamming et al. 1994]). Five out of twenty subjects used event-based cues to find information in their notes. Changing the original sequence of notes by regrouping them (as described in Section 7.2) destroys mapping between notes and events. It is interesting to note, that, as reported by the subjects, four out of five subjects who used event-based cues never rewrites their notes, while the other does it only occasionally. This observation confirms again a wide range of individual note-taking habits.

The advantage of EEN is that it allows for both preserving the original order of notes, and, at the same time, thematic regrouping of notes.

7.4 Categorizing information

7.4.1 Categorizing during note-taking

Categorizing during note-taking involves two kinds of difficulties. First, performing the categorization itself. Second, performing it while taking notes. We observed both of these difficulties during our experiment in FORM condition. The first type of difficulties appeared also after note-taking in FFP condition and we describe separately in the next section (Section 7.4.2).

We observed that all subjects in the FORM condition had problems with selecting an appropriate form. This was additionally confirmed by the number of empty forms. On the average 2.8 empty forms (14% of all pages) were left in between the full forms. Some subjects immediately deleted pages with empty forms, thus the number of empty forms was even higher. Further difficulties were caused by selecting appropriate fields within forms. Problems with categorizations contributed additionally to the “wrong” use of forms as described in Section 7.1.1.

Furthermore, four out of seven subjects complained about the unnecessary, and not natural for them, detailed categorization, and, as described earlier (Section 7.1.3 and also Section 6.1), expressed their preference for grouping notes on one page.

A different way of minimizing categorization necessary during the note-taking activity was implied by subject FORM1, who suggested preparing (defining and pre-filling) forms before a planned activity (e.g. a meeting scheduled for a specific project).

7.4.2 Post-categorizing

In the FFP condition categorization was applied after note-taking, and we observed that subjects, in general, did not have problems with using the categorization mechanisms after taking the notes.

This observation, along with those discussed in the previous section (7.4.1), confirm Expectation 2a.

However, categorization performance (in the sense of selecting a semantic label) was still problematic. Four out of seven subjects mentioned difficulty with choosing labels. These difficulties were often caused by the inability to differentiate the meanings of terms used for labels. In the interview after the first session, even subjects who performed categorization very meticulously, said that it was not natural for them, and that they "do not think in terms of rationale, parts, and parameters".

In the FFU condition subjects created their own labels, and thus the difficulty in understanding and being able to differentiate terms used for labels did not exist. Furthermore, terms used by subjects were more specific and less abstract. Subjects used concrete terms three times as often as the abstract ones[1] (see Figure 37 and Section 7.4.4). Concrete terms were rarely reapplied (0.33 - an average reuse[2] of concrete terms in FFU), while abstract ones more often (1.67). Thus the term selection problem was additionally alleviated by the term specificity - in most cases labels with concrete terms did not have to be reused in the short design meeting (see also Section 7.4.8 discussing terminology reuse) used in the experiment.

These observations confirm Expectation 2b.

7.4.3 Categorization strategies adopted by subjects (FFP and FORM)

Subjects adopted several strategies to deal with categorization difficulties.

In the two conditions with domain-based terminology (FFP and FORM), five out of fourteen subjects dealt with difficulties in categorization by adopting one category as a "miscellaneous" container. For example, subject FFP5 adopted "requirement" and subject FFP6 adopted in such a way

1. Usage of terms refers to definitions of user labels, not to their application in notes (see the next footnote).
2. Reuse refers to the number of repeated occurrences of a user-defined label in notes.

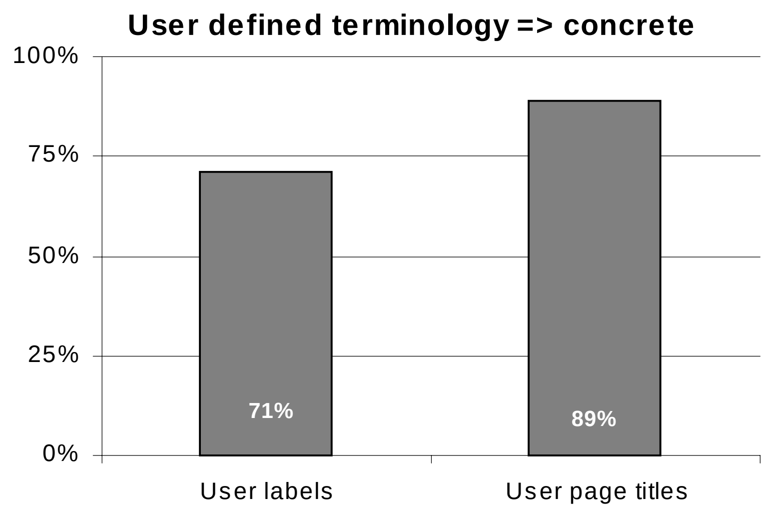
"parameter". The use of the special container was also apparent during the information finding session; when all other categories failed, these subjects checked their "miscellaneous" category. In a similar way, subjects FORM2 and FORM7 employed the "description" field in different forms, and subject FORM6 the "generic description" form.

Other subjects used gross categorization in which they applied one label to a group of notes, thus avoiding detailed categorization. Furthermore, our observations and interviews indicate, that gross categorization may be sufficient for subjects in their current note-taking practices. Subjects look for information in their notes by first locating a general topic and then visually scanning the area of notes for detailed information.

7.4.4 Abstract vs. concrete terminology

Terminology defined by subjects for their labels in the FFU condition tended to be concrete rather than abstract. Subjects used concrete terms three times as often as abstract ones (see Figure 37). The same relationship between abstract and concrete terminology was observed in names used for page titles.

Figure 37. Usage of concrete terminology in the FFU condition



For example, subjects used specific parameters (e.g. "key size", "temp range", "depth"), rather than classifying them as "parameter". Similarly, subjects used "keypad", "battery", rather than calling them a "part". (For the full list of user-defined terms see Appendix F, Table 22 and Table 23.)

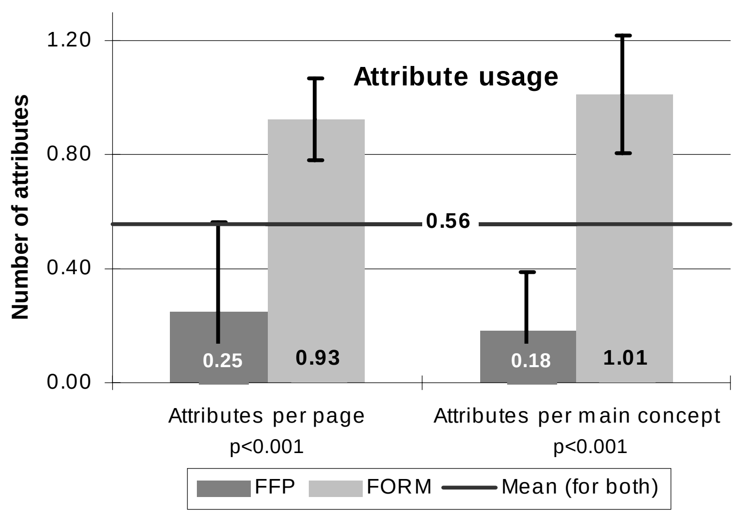
The preference for concrete terminology was confirmed by observations of information finding strategies and during interviews with subjects. Subjects had most difficulties with abstract product structure terms used in the FFP and FORM conditions (e.g. requirement, part, parameter). No such problems were observed with project management items (e.g. action, meeting).

7.4.5 Attributes and relations (FFP and FORM)

Attributes and relations provide additional structure to recorded concepts.

Five out of seven subjects, in the FFP condition, used attributes. Their usage, however, was very sporadic - only 18% of the main concept labels had attributes attached to them, and the attributes were used only on 25% of pages. On the other hand, all subjects in the FORM condition used attributes - on the average one attribute per form.

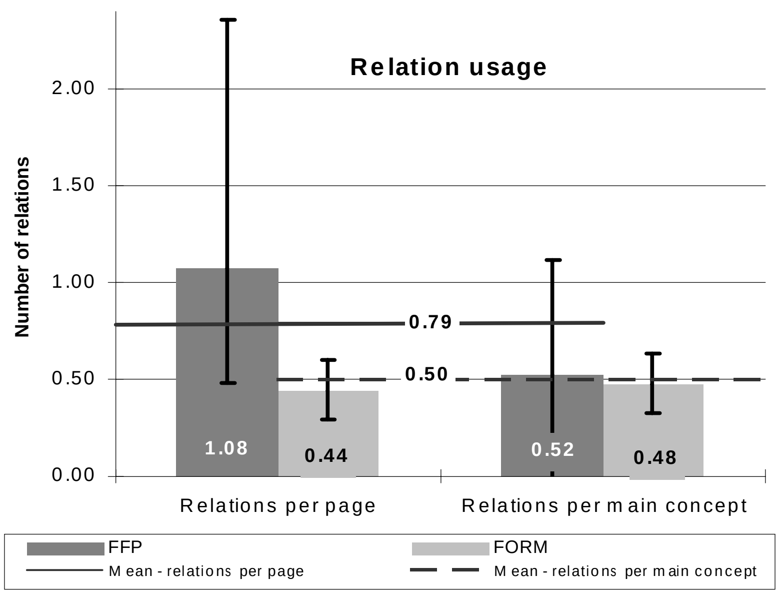
Figure 38. Attribute usage



The average number of relations per main concept used in the FFP and FORM conditions was similar and around 0.5. However, when we compare the individual usage of relations in these experiment conditions, all “FORM” subjects employed relations, while only four out of seven FFP subjects did.

In the FFP interface, attributes and relations were attached to the main concepts by adding a subsequent label to an object already labelled with a main concept. In the FORM interface, adding an attribute or relation required filling out a field on a form.

Figure 39. Relation usage



In the FFP subjects used very few attributes because attaching them required additional actions, while not giving sufficient advantages. On the contrary, the extra detailed categorization provided by attributes was perceived by subjects as difficult and unnecessary (see Section 7.4.3). On the example of subject FFP6, who only used attributes and no relations, in the second session we observed, that subject was looking either for main concepts or for attributes, but not for both. Thus single labelling of objects could be more appropriate for the subjects.

Relations were employed more frequently than attributes in the FFP condition. The additional effort needed to attach relations was possibly justified by the potential later usefulness of additionally provided functionality (active links between related objects). Nevertheless, five out of seven subjects in FFP condition complained about linking being too complicated and too “hard to grasp”. These subjects suggested one generic type of link instead of specialized semantic linking. Again, subjects seemed to like the potential usefulness of linking, but do not like the additional detailed categorization. Furthermore, one of the six subjects in FFU condition, which did not allow for linking, suggested linking labels as a possible feature.

From the four FFP subjects who applied links, only one (FFP2) made use of them during the retrieval session. Additional explanation of the difficulties with using links can be found in the model of human information processing. FFP content with linked FFOs becomes an associative network of concepts. The structure of human memory is associative, however, the process of acquiring new information by humans from the environment is linear [Parsaye et al. 1993], and thus acquiring associative (nonlinear) structures is difficult. On the other hand, the structure in the FFP had been created by the same person who was using it to find information. One could thus argue, that this structure already exists in user’s memory, and that during retrieval no effect of acquiring new information appears. We don’t know, however, how much of the structure was retained in user’s memory.

The mechanism of adding attributes and relations in the FORM condition was easier. It did not require additional operations on the user interface, however, it still required performing more detailed categorization.

Infrequent use of additional attribute and relation labels, observed in the FFP condition, can be explained both by the difficulty in using the mechanism, and by the difficulty in applying detailed categorizations.

7.4.6 Categorizing during information retrieval

Finding specific information in a notebook requires reapplying categorizations. We observed that subjects categorized information from questions differently than they initially categorized the content. In some cases subjects recognized this problem, and avoided categorizing questions by employing other methods of information access, for example, flipping through all pages. We divided information finding strategies into two main groups: “trust strategies” and “no-trust strategies”. For a detailed discussion see page 63.

7.4.7 Terminology as a reminder

Several subjects recognized positive role of the pre-defined terminology. For example, four subjects (FFP7, FORM1, FORM4, FORM5) noticed that providing structure, in a sense of pre-defined categories, helped them to focus and to make sure that all required items are covered. These subjects had less problems with terminology, which can explained by their professional (3 out of these 4) or research (1) experience. However, seeing the positive role of terminology does not indicate yet, how to provide it. Subject FFP7 suggested free-form interface provided with titles corresponding to main concepts and displaying context-sensitive menus with further details (attributes) for each main concept.

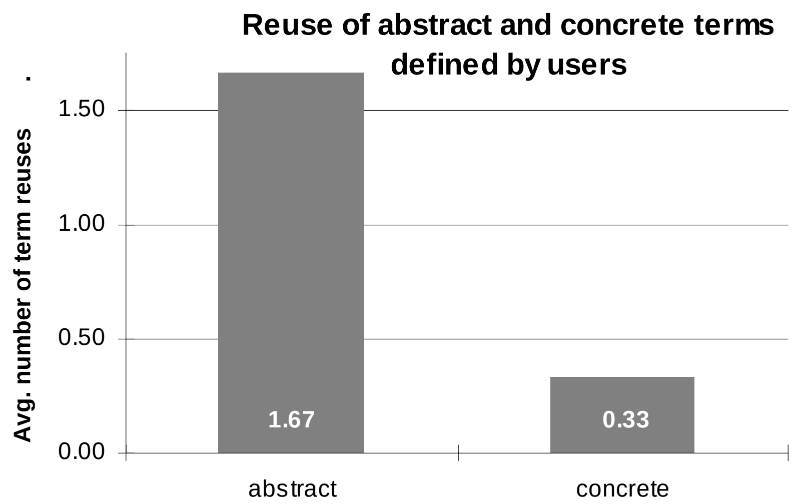
All FORM subjects mentioned here still experienced the difficulties with thematic note-taking in forms. Hence, these observations do not necessarily suggest that forms are appropriate for providing terminology. To answer this question a long term study with professional engineering designers should be conducted.

7.4.8 Reuse of terminology

Abstract labels facilitate reuse of the terminology. We measured the reuse[1] in FFU condition. Abstract terms were reused more often than concrete terms. (Figure 40)

1. Reuse of terms was calculated as:
   (number of term occurrences - number of different terms) / number of different terms

Figure 40. Terminology reuse in FFU



Abstract labels can be often reused in marking notes, however abstract terminology is difficult to understand (see earlier discussion in Section 7.4.4). On the other hand, specific terms are easier to understand for subjects, but require using more labels to mark notes, and, thus, with growing number of notes, it may become difficult to manage and to remember their usage. Similar patterns of low user-defined keyword reuse were observed in other information indexing studies [Ward 1995]. A combination of both, abstract and concrete terminology may offer a proper solution. Abstract terminology would be mostly pre-defined and used for lower level detail, while concrete terminology would be user-defined and used for higher level terms (chapters, projects names, etc.). A similar approach was suggested by two subjects.

8. Results Summary

8.1 Note-taking

We observed that form-based interface forced subjects to modify their note-taking habits, while free-form interface did not[1]. Notes were more complete in the free-form conditions than in the form condition. Furthermore, suggestions for flexible forms indicated a user preference for unconstraining interfaces, and thus point towards a free-form approach.

Users note-taking habits were idiosyncratic and we could not assess during our experiment to what degree these habits are flexible, or how quickly users form new habits[2].

8.2 Structuring

Results from our experiment indicated that, to compare interfaces with regard to information structuring, we need to make a distinction between the information structuring mechanisms, used to separate elements of structure and the information categorization required by semantic structuring.

Our observations confirmed, that, by virtue of delayed structuring, the free-form interface was easier to use than forms with fixed structure which forced users to break down notes during their creation.

While the structuring mechanism is a function of user interface, the terminology used for semantic categorizations is independent of the user interface. We observed difficulties with categorization in both free-form and form-based interfaces.

1. Note-taking habits could be employed within limits of the implementation technology (e.g. screen size, system speed, separate pen-tablet and display).
2. This should be addressed in a future long term field study

Subjects in those conditions employing domain-based terminology had problems with differentiating terms and with their use. These problems were not observed with subjects used their own terminology, which they were, obviously, familiar with. In addition, subjects' terms tended to be concrete most of the time (71%). Concrete terms, because of their specificity, were rarely reapplied again (0.33 - an average reuse of concrete terms in FFU), and thus subjects rarely needed to reconsider their meaning.

8.2.1 How much categorization is enough?

We observed many problems with detailed categorization. Subjects were not used to performing detailed categorizations of their notes, since they employ other means of accessing notes in their note-taking practice. For example, they use page layout and special marks to visually perceive page structure; they use event memory to locate specific information. The combination of disparate and, at the same time, complementary methods allow them to effectively find information in the notes.

The form-based interface forced subjects to create more detailed structure than free-form interfaces. Much of that structure was unnecessary, since it did not increase the number of design meeting concepts structured in the FORM condition.

We need to consider the purpose for providing structure and categories. Observations from our experiment seem to indicate that providing structure to facilitate human information processing requires quite different approach than providing it to facilitate machine information processing. Detailed categories may be good for machine information processing, however, they seem to be very difficult to use by people, and thus not appropriate for facilitating human information retrieval from notes.

We also need to consider the user task. In the context of taking notes from a design project meeting, a small project (like the one used in our experiment) may require less categories than a large one, and thus subjects were overwhelmed with the number of concepts provided for information categorization. In some cases, this effect might have been compounded by their lack of experience.

Furthermore, the difficulties with detailed categorization, and patterns of attribute and relation usage, indicate that one label per object is sufficient for users, and that general linking, rather than semantic, is more appropriate.

8.2.2 Expert use of terminology

Experts had less problems with terminology (both with applying it, as well as with using it during information retrieval). Experts used categorization-based search ("trust" strategies) more often then novices, and were able to find information in a smaller number of categorization-based steps.

In addition, a number of expert users noted a positive role of terminology as a reminder and as a help in focusing the process (e.g. what should be covered in a design meeting under particular topics). However, the current findings do not indicate which way of providing terminology would be best.

Chapter 5

Conclusions

"Nothing is brought to perfection on its first invention."
Cicero, "Brutus"

1. Summary

This work was motivated by problems with accessing engineering design information generated in the initial design stages and traditionally recorded in paper engineering notebooks. The focus of the thesis was on non-intrusive methods of semantic information structuring facilitating subsequent information access.

An Electronic Engineering Notebook was designed and implemented. The EEN supports free-form interaction, and allows for semantic information structuring using terminology based on engineering ontologies. The EEN employs context sensitive labelling and linking in context.

An experiment was conducted in which free-form and form-based interfaces were compared with respect to capturing and structuring notes from a design meeting. Furthermore, suitability of domain-based and user-defined terminologies for semantic structuring was tested.

Results from the experiment confirmed that free-form interface was easier to use for note-taking than were forms with fixed structure. Furthermore, based on these results, an important distinction needs to be made between structuring mechanism and semantic categorizations required by structuring. While the structuring mechanism is a function of the user interface, the terminology used for categorization is independent of the user interface. Delaying structuring in free-form interface made that interface easier to use than forms. However, difficulties with applying semantic categorizations were observed in both types of interfaces. Furthermore, the results indicate that terminology should be chosen appropriately to a task, and that experienced users have less problems with applying it. The experiment also demonstrated high diversity in note-taking styles thus highlighting the need to accommodate individual preferences in electronic notebooks.

2. Recommendations

2.1 Design of the EEN

EEN interface should be extended and made more flexible to accommodate individual differences in note-taking habits. For example, user preference for sequential note-taking and thematic organization of notes for information retrieval could be accommodated by supporting optional regrouping of notes after their structuring.

Higher reuse of abstract terminology and problems with its usage, contrasted with potential difficulties in managing a growing number of concrete terms and ease of understanding these terms suggest that both terminology types should be combined in one interface; providing pre-defined, domain-based terms, and allowing users to add their own terms. For example, abstract terminology could be pre-defined and used for lower level details, while concrete terminology could be user-defined and used for higher level elements in the notebook structure (e.g. product names, projects names, etc.). Employing user-defined terminology for higher level elements would help to limit their number and to make user terminology better manageable.

Considerations of terminology fitness for a task, indicate possibility of suppling a flexible set of terms selected according to user experience and to the type and size of a design project.

The difficulties with detailed categorization, and patterns of attribute and relation usage, indicate that one semantic label per object is sufficient for users, and that general linking, rather than semantic, is more appropriate.

2.2 Experimental methodology

2.2.1 Independent measures

Analyses of experiment results indicates that other independent factors may also need to be considered in note-taking studies. Engineering design experience was used by us as an independent measure in this study. Information on the experience was self-reported by subjects. Since experiment participants were recruited from university students, our definition of experience and included relatively short periods of practical engineering experience and experience gained in the academic environment.

Furthermore, our observations, interviews and subjects' notes analysis, indicated that other factors may be more appropriate for consideration in addition to, or instead of, experience, or that the definition of experience should be modified. Note-taking habits were idiosyncratic and ideally should be taken into account as well. If subjects' note-taking habits were known, we could better explain the differences in coverage of meeting concepts in notes. The difficulty lies in obtaining objective measure of note-taking habits. In future, these could possibly be obtained by observing subjects and analyzing the notes taken by them in the course of several note-taking sessions. Organization abilities are especially important in structuring information, although these are also highly idiosyncratic and hard to measure. An important additional factor to consider might be the ability of applying organization skills in the context of engineering note-taking. Experience in taking notes of various types could also be considered. All of our subjects had experience in taking lecture notes and most of them had experience in taking meeting notes, however, only a few had longer experience in this activity.

2.2.2 Experiment conditions

In our experimental design, subjects were using different interface variants. In order to further explore the role of terminology versus the role of structuring mechanism, the same subjects could use different interfaces in the course of a long term study comprising of several note-taking sessions.

2.2.3 Training session

The difficulties with using pre-defined terminology indicate the importance of providing training to users. For example, in future experiments a separate introductory session involving usage of pre-defined terms in a test note-taking task could be conducted.

3. Contributions

1. Design of an electronic engineering notebook

   Novel features of the design included: using terminology based on engineering ontologies for semantic information structuring of engineer's notes, context sensitive labelling, and linking in context.

2. Design of experimental methodology for note-taking studies

   Contributions to the experimental methodology include: design of independent measures to examine note structuring mechanisms and terminologies used for semantic structuring. Devising dependent measures to test different aspects of note-taking, note-structuring and information retrieval from notes. Design of a note-taking task and recording of a design meeting as a video which provided identical information to all subjects.

3. Research results

   The most important results are: higher efficiency of note-taking in free-form than in fixed-form interface; dominant use of concrete terminology in user-defined labels; effect of experience on reapplying categorizations and on performing categorization-based search.

4. Recommendation for design of engineering electronic notebooks and for experimental methodology

   Based on the findings from the experiment, improvements in the design of the EEN were suggested, along with changes to the experimental methodology.

4. Directions for the Future Research

Our findings from the experiment should be used to revise the EEN's design. The revised EEN should be used to conduct further studies. The studies should examine long term note-taking usage in a professional engineering environment.

Some research questions raised in the course of this work:

- How much structure is sufficient and how does it depend on a task?
- What is the optimal way to provide terminology (terminology as a reminder)?
- How to best combine domain-based and user-defined terminology?

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Appendix A

Structures in Electronic Notebooks

1. Levels of structured content in electronic notebooks

In the context of free form interaction interfaces for electronic notebooks we can distinguish four levels of structuring content (see Table 7 below).

Table 7: Structure level in the context of free-form electronic notebooks

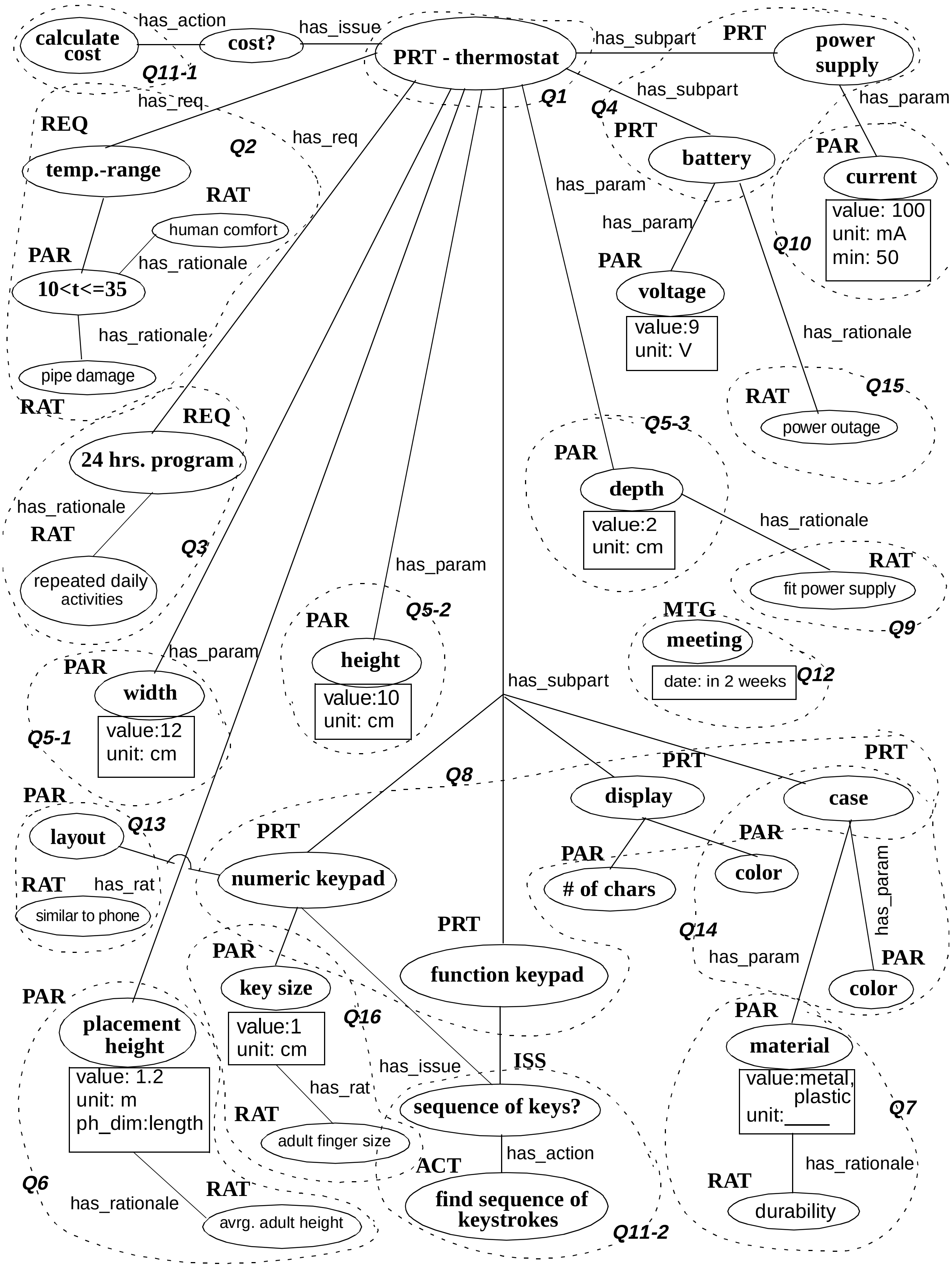
	Level	Type of structures and the role of system support
1	*Free form* object	Detection of lowest level objects. Automatic, based on time and position, and manual.
2	*Free form* object with internal structure	Emergent structures in lowest level objects. System “works with” user guiding his perception, for example, by suggesting structures emerging in sketches.
3	Collection of *free form* objects - no semantics	Structures implicit in arrangement of objects. System “learns” structures existing implicitly in collections of objects.
4	Collection of *free form* objects with *semantics*	Free form objects have semantics attached to them. Relations between objects can be inferred by the system based on level 3 structures.

In this thesis we are interested in the fourth level.

Appendix B

Design Project Used in Experiment

Figure 41. Hierarchy of concepts used in the design meeting with question numbers*



(* List of questions is provided in Appendix C)

Appendix C

Handouts for Experiment Subjects

Task description for an experiment subject

Your Task

You are a member of a design team. Your name is Joe. You have not attented the last design meeting. However, the meeting has been video taped. You need to understand the design project that was initially discussed and worked on during this meeting. You need to know what are the design requirements, what parts were discussed, what are the components (parts), what are their parameters (e.g. their size) and their values. You should make note whether any of the discussed elements or values were justified and what was the justification. You also need to know what actions are to be taken next by you, that is by Joe. To do this you watch the video and take notes. You are expected to write most of the time while watching the video and to take notes on all concepts mentioned in the video. (If you need more time, you can pause or rewind the videotape at any time.) Later your notes will be serving you as a source of design information and you will refer to them to find the information.

Session 1

1. Explanation of your task.
2. Explanation of the user interface and a short practice.
3. Watching a video from the design meeting and taking notes.
4. Organizing and structuring notes.
5. Short interview.

Session 2

1. Explanation of your task.
2. Finding information from the design meeting. You will use your notes taken in the first session to find the appropriate information. You will be asked to talk outloud as your search your notes.
3. Short interview.

Form filled out in step 4 of the first session by subjects in the FORM condition.

Requirement:

Part:

Parameter:

Rationale:

Issue:

Action:

Meeting:

Generic (Description):

Questions for the second experiment session. Maximum possible score is given in brackets.

1. What was the topic of the design meeting? (1)
2. What temperature range was to be controlled by the device? and why? (2)
3. What was the thermostat’s period of programming? Why was it was appropriate? (2)
4. How many power sources was the unit supposed to have? (2)
5. What were the dimensions of the device? (2)
6. Could the unit be mounted at a different height? (2)
7. Which materials were considerd to use for the case? What criteria were mentioned? (2)
8. How many main parts does the unit have? (2)
9. Why its depth was 2cm? (1)
10. What power supply’s parameter minimum value did they mention? (2)
11. What do you have to do for the next week? (2)
12. When is the next project meeting, related to this device, scheduled? (1)
13. What was the reason for the numerc keypad’s layout? (1)
14. What color schemes and for which parts were discussed? (2)
15. Why the battery was to be used? (1)
16. What was the size of the keys? and why? (2)

Appendix D

Experiment Interview Questions

1. Interview after the first session

Note-taking habits:

1. Do you take notes? If yes, in what situations do you take notes?

2. What type of notes do you take?

3. Do you organize your notes? If yes, how?

4. Do you rewrite your notes?

5. Do you mark your notes? If yes, how?

6. Do you go back to your notes? if yes, how far back and how often?

7. Do you have any other note-taking habits?

8. (Specific Questions based on observation of subject's behaviour and on debriefing)

9. What are your general impressions from using the system to take notes?

10. Would you like to add anything else?

Subject's background and experience:

11. What program are you enrolled in? What year?

12. Do you have industrial engineering design experience? How many years?

13. Do you have research engineering design experience? What kind?

Appendix E

Experiment Protocol and Consent Forms

Video Tape Release Consent Form

Design Session Video Tape

I hereby agree that the video tape “Design Session” in which I acted will be viewed by subjects in the experiment entitled “Design Note-taking Using Electronic Notebooks” that is being carried out under the auspices of the Mechanical and Industrial Engineering Department at the University of Toronto by Jacek Gwizdka. The video will only be viewed by subjects during this experiment, and cannot be used for any other purpose, unless I give explicit permission that it be used for that purpose.

I consent this release voluntarily and without any coercion.

Name: ___________________________

Signed: __________________________

Date: ____________________________

Investigator: Jacek Gwizdka

Supervisor: Prof. Mark Fox

Department of Mechanical and Industrial Engineering

Protocol for Permission to Carry out the Experiment Described Herein Using Human Subjects

Investigator: Jacek Gwizdka

Supervisor: Prof. Mark Fox

Purpose:

This document describes experiment to be conducted within the framework of Jacek Gwizdka's Masters research. The experiments will focus on comparing three computer interfaces: a free-form interface with domain-based keywords, a free-from interface with user defined keywords, and a forms-based interface, with respect to design-related note-taking. The study will consist of a note-taking part and a notes retrieval part.

Subjects:

The experiment will require 20 to 30 subjects. Subjects for the experiment will be drawn from the undergraduate/graduate students from the Department of Mechanical and Industrial Engineering.

Before subjects agree to participate in the experiment, they will be given a description of the study. They will also be assured of the complete confidentiality of the data collected. Each subject willing to participate will be asked to sign a consent form (see attached) to participate in the experiment.

Subjects will each take part in two approximately one hour experiment sessions and will be paid a total of $20 for their participation.

Procedure:

The first experiment session will be preceded by a short training, the purpose of which will be to explain the system interface and familiarize subjects with the terminology used. During the course of the first session subjects will be asked to take notes while watching a video from a design meeting. They will be allowed to control the video and pause it for a reasonable amount of time when they wish. After the video ends subjects will be asked to review and organize their notes.

The second session will be run after about one week. Subjects will be asked questions about the design meeting they watched in the first session and will be asked to find answers by performing information retrieval from their previously taken notes. Subjects will be allowed to pause for a reasonable amount of time between questions. We will register the number of correct answers and record the time and the actions that subjects performed to find the answers. At the end of the second session subjects will be asked questions in an interview style by the experimenter to gain more insight into their subjective experience with the system.

Design session video tape:

The video tape used in the first session contains a design meeting during which requirements for a design of a simple user interface for a home appliance are presented, design with possible alternative solutions are discussed and justified, and actions to be performed by design team members are outlined.

Risks and Benefits:

There are no expected risks to the subjects.

This research will provide useful information about the viability of free-form interaction style for use in electronic notebook interfaces in the context of capturing design information.

Information to be collected in the experiment:

Notes taken by subjects in the first session will be electronically collected by the experimenter. Answers to questions and time and actions taken to find them will be collected. Notes written by experimenter on the search strategies employed and during interviews will also be collected. Personal information (e.g., name, phone number or e-mail address) will be used for identification and contact purposes only.

Confidentiality of the collected data:

All subjects' data will be identified by confidential codes. Information such as subjects' names, e-mail addresses and phone numbers will be kept separately from the subjects' performance data and will not be used in any internal or external reports without the subjects' explicit consent.

Only summaries of the data will be presented in the thesis and no such summary will contain data which in any way identifies individual subjects.

Subject Consent Form

Design Note-taking Using Electronic Notebooks.

I hereby agree to act as a subject in an experiment entitled “Design Note-taking Using Electronic Notebooks” that is being carried out under the auspices of the Mechanical and Industrial Engineering Department at the University of Toronto.

I have been given a full description of what I shall be required to do in this investigation. I am aware that I may withdraw from the investigation at any time, and that I have the right to ask in that case for any data collected about my performance to be given to me or destroyed.

I understand the experiment will consist of two sessions a week apart each lasting approximately one hour and I will be paid $20 ($10 per hour) for my participation.

I consent to take part in this experiment voluntarily and without any coercion.

Name: ___________________________

Signed: ___________________________

Date: _____________________________

Investigator: Jacek Gwizdka

Supervisor: Prof. Mark Fox

Receipt

I received twenty dollars ($20) for my participation in the experiment "**Design Note-taking Using Electronic Notebooks**".

Name: ___________________________

Signed: ___________________________

Date: _____________________________

Investigator: Jacek Gwizdka

Supervisor: Prof. Mark Fox

Appendix F

Tables with Experiment Results

Subject Data	#	Category	Expert (ind or res)		pgs	full pgs	pgs w/tags	pgs w/o tags	named pgs
							Page Usage		
FFP	1	U4, Mech	1		10	10	5	5	0
FFP	2	G, Ind, HF	1		15	15	13	2	0
FFP	3	U4, Mech	0		14	13	11	2	0
FFP	4	U3/4	0		8	9	7	2	0
FFP	5	U3, Mech	0		16	15	14	1	0
FFP	6	G, Ind, HF	0		14	13	13	0	0
FFP	7	G,Ind	1		3	3	0	3	0
					11.43	***11.14***	***9.00***	***2.14***	*0.00*
					pgs	**full pgs**	**pgs w/tags**	**pgs w/o tags**	**named pgs**
FFU	1	U4, Mech	0		3	2	2	0	0
FFU	2	G/U, Mech	1		13	13	8	5	0
FFU	3	G, Mech	1		7	7	7	0	6
FFU	4	U3, Mech	1		6	6	6	0	0
FFU	5	G, Ind, IS	0		4	4	2	2	0
FFU	6	G,Mech	1		6	6	6	0	0
					7.00	***6.80***	***5.80***	***1.00***	*1.20*
					pgs	**full pgs**	**empty pages**	(N/A)	**named pgs**
FORM	1	G, Ind, HF	1		16	13	3		11
FORM	2	U3, Mech	0		20	20	0		10
FORM	3	G, Mech	0		17	11	6		0
FORM	4	G,Mech	1		25	24	1		0
FORM	5	G,Mech	1		23	21	2		1
FORM	6	U3, Mech	0		19	18	1		
FORM	7	G,Ind	0		19	17	2		0
				Avg.	*19.86*	***17.71***	*2.14*		*3.67*

Table 8: Subject data and page usage

Table 9: Label usage

Cond	#	tags	m.tags	all attr tags	A attr tags	A rel tags	Separ. tags	Total tags	tags/ page	tags/ page w/t	m.tags/ page	m.tags/ page w/t	all attr/ page	A rels/ page	all attr/ page w/t	A rels/ page w/t	all attr/ m.tags	A rels/ m.tags	Remarks to data
										Label (Tag) Usage									
FFP	1	11	10	1	0	2	11	13	1.10	2.20	1.00	2.00	0.10	0.20	0.20	0.40	0.10	0.20	
FFP	2	30	29	2	1	43	30	74	2.00	2.31	1.93	2.23	0.13	2.87	0.15	3.31	0.07	1.48	
FFP	3	33	33	1	1	32	33	66	2.54	3.00	2.54	3.00	0.08	2.46	0.09	2.91	0.03	0.97	
FFP	4	11	8	3	0	0	11	11	0.89	1.14	0.89	1.14	0.33	0.00	0.43	0.00	0.38	0.00	
FFP	5	29	29	0	0	14	29	43	1.93	2.07	1.93	2.07	0.00	0.93	0.00	1.00	0.00	0.48	
FFP	6	22	22	11	11	0	22	33	1.69	1.69	1.69	1.69	0.85	0.00	0.85	0.00	0.50	0.00	
FFP	7																		no tags, see 1)
		22.67	***21.83***	*3.00*	*2.17*	*15.17*	***22.67***	*40.83*	*1.69*	*2.07*	***1.66***	***2.02***	***0.25***	***1.08***	*0.29*	*1.27*	***0.18***	***0.52***	
		tags	(same)	(N/A)	(N/A)	(N/A)	(same)	**Total tags**	**tags/ page**	**tags/ page w/t**	(same)	(same)							
FFU	1	6	6				6	6	3.00	3.00									
FFU	2	11	11				11	11	0.85	1.38									
FFU	3	17	17				17	17	2.43	2.43									
FFU	4	14	14				14	14	2.33	2.33									
FFU	5	2	2				2	2	0.50	1.00									
FFU	6	22	22				22	22	3.67	3.67									
		14.00	***14.00***				***14.00***	*14.00*	***2.45***	***2.56***	***2.13***	***2.30***							
		tags	**m.tags** forms-de	**attr tags**	**attr "main"**	**rel tags**	**Separ. tags**	**Total tags**	**tags/ page**	(N/A)	**m.tags/ page**		**attribs / page**	**rel tags/ page**	**attr-main/ page**	**attr-main/ m.tags**	**attribs / m.tags**	**rel tags/ m.tags**	
FORM	1	31	11	15	1	5	31	31	2.38		0.85		1.15	0.38	1.08	1.27	1.36	0.45	
FORM	2		20																data lost, see 2)
FORM	3	28	10	12	0	6	28	28	2.55		0.91		1.09	0.55	1.09	1.20	1.20	0.60	
FORM	4	61	23	23	0	15	61	61	2.54		0.96		0.96	0.63	0.96	1.00	1.00	0.65	
FORM	5	43	20	18	0	5	43	43	2.05		0.95		0.86	0.24	0.86	0.90	0.90	0.25	
FORM	6		18								1.00								data lost, see 2,3)
FORM	7	37	16	14	3	7	37	37	2.18		0.94		0.82	0.41	0.65	0.69	0.88	0.44	
		40.00	***16.86***	*16.40*	*0.80*	*7.60*	***40.00***	*40.00*	*2.34*		***0.93***		***0.98***	***0.44***	***0.93***	***1.01***	***1.07***	***0.48***	

1) first did not use tags, repeated note-taking with tags, but error in data, cannot be read. FFP2 used in sess.2

2) data lost. FORM4 used in sess. 2

3) partial results written from mem write after the 1st session

Table 10: Coverage of design meeting concepts measured by answers to questions

	#	Concept coverage and structure - scores for questions from the second session																								(Score content coverage / structure)								Total	
		1	1str	2	2str	3	3str	4	4str	5	5str	6	6str	7	7str	8	8str	9	9str	10	10str	11	11str	12	12str	13	13str	14	14str	15	15str	16	16str	Cont.	Str.
		1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2	1	1	1	1	2	2	1	1	2	2	27	27
	1	1	1	2	1	2	2	2	2	2	0	2	0	1	1	2	1	1	0	2	0	2	1	1	0	1	0	2	1	1	0	2	0	0.96	0.37
	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2	1	1	1	0	2	2	1	0	2	1	1.00	0.89
	3	1	0	2	2	2	2	2	0	2	0	2	2	2	2	2	2	1	1	2	0	2	2	1	1	1	0	2	2	1	1	2	2	1.00	0.70
FFP	4	1	1	1	1	1	0	1	1	2	0	1	0	2	0	2	0	1	1	1	0	2	1	1	1	1	0	2	0	1	1	2	0	0.81	0.26
	5	1	1	2	2	2	2	2	2	2	1	2	1	2	2	2	1	1	0	2	1	2	2	1	0	1	1	1	0	1	0	1	0	0.93	0.59
	6	1	1	2	2	2	2	2	0	2	1	2	2	1	0	2	1	2	1	2	0	2	2	1	1	0	0	1	1	1	0	1	1	0.89	0.56
	7	1																																	
		1	0.83	1.83	1.67	1.83	1.67	1.83	1.17	2	0.67	1.83	1.17	1.67	1.17	2	1.17	1.17	0.67	1.83	0.5	2	1.67	1	0.67	0.83	0.17	1.67	1	1	0.33	1.67	0.67	**0.93**	**0.56**
		Avg.																																	
	1	1	0	1	0	1	0	2	1	2	0	2	0	2	0	1	0	1	0	2	1	0	0	1	0	1	0	1	1	1	1	0	0	0.70	0.15
	2	1	0	2	0	2	1	2	0	2	1	2	1	2	1	1	1	1	0	2	0	2	2	0	0	1	0	1	0	1	0	2	1	0.89	0.30
FFU	3	1	1	2	1	2	0	2	2	2	1	2	1	2	2	1	1	0	0	2	1	2	2	1	1	0	0	1	1	1	0	2	1	0.85	0.56
	4	1	1	1	1	2	1	1	1	1	1	2	1	2	1	1	1	1	1	0	0	2	2	0	0	0	0	1	1	1	0	1	1	0.63	0.48
	5	0	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	2	2	1	0	0	0	0	0	0	0	0	0	0.26	0.15
	6	1	0	2	2	1	1	1	0	2	1	2	2	2	1	2	0	1	1	1	0	2	2	1	1	1	1	1	1	0	0	2	2	0.81	0.56
		1	0.4	1.6	0.8	1.6	0.6	1.6	0.8	1.8	0.8	2	1	2	1	1.2	0.6	0.8	0.4	1.4	0.4	1.6	1.6	0.6	0.4	0.6	0.2	1	0.8	0.8	0.2	1.4	1	**0.78**	**0.41**
		^Avg.																																	
		no 5																																	
	1	1	0	2	2	1	0	0	0	2	2	2	1	0	0	2	1	2	2	0	0	2	2	1	0	1	0	2	1	0	0	2	1	0.74	0.44
	2																																		
	3	1	0	1	1	2	2	2	2	2	2	2	1	2	2	2	1	0	0	2	2	2	2	1	1	0	0	2	1	1	1	1	0	0.85	0.67
FORM	4	1	0	2	2	2	2	2	2	2	2	2	2	1	1	2	2	0	0	2	2	2	2	1	1	1	1	1	2	1	1	1	1	0.85	0.85
	5	0	0	2	2	2	2	1	1	0	0	2	2	2	2	2	2	0	0	0	0	2	2	0	0	0	0	1	1	0	0	2	2	0.59	0.59
	6																																		
	7	0	0	2	0	2	0	1	1	2	0	2	0	1	0	2	0	0	0	0	0	2	2	0	0	0	0	1	0	0	0	2	2	0.63	0.19
		0.6	0	1.8	1.4	1.8	1.2	1.2	1.2	1.6	1.2	2	1.2	1.2	1	2	1.2	0.4	0.4	0.8	0.8	2	2	0.6	0.4	0.4	0.2	1.4	1	0.4	0.4	1.6	1.2	**0.73**	**0.55**
		Avg.																																	

	FFP	FFU	FORM
Coverage of concepts:	0.93	0.78	0.73
Degree of structure:	0.56	0.41	0.55

Table 11: Time note-taking, organizing and total (minutes)

Cond	#	Time Time note-taking and watching video (min)	Time organizing (min)	Time Total
FFP	1	30	15	45
FFP	2	19	29	48
FFP	3	36	37	73
FFP	4	31	10	41
FFP	5	24	28	52
FFP	6	23	29	52
FFP	7	25	15	40
FFU	1	30	17	47
FFU	2	18	13	31
FFU	3	12	16	28
FFU	4	35	21	56
FFU	5	40	30	70
FFU	6	18	19	37
FORM	1	41	0	41
FORM	2	75	0	75
FORM	3	49	0	49
FORM	4	53	0	53
FORM	5	41	0	41
FORM	6	14	0	14
FORM	7	47	0	47
				Total
Avg. Times		33.05	21.46	47.00
FFP		26.86	23.29	**50.14**
FFU		25.50	19.33	**44.83**
FORM		45.71	0.00	**45.71**

Table 12: Note-taking habits (interview after the first session)

		Interview	Note-taking habits								
Cond	#	Organize	Dates	Page titles	Rewrite	Keyw.	Summary	Import.	Neat notes	Other	Access
FFP	1	not a lot, not after	yes	yes	rare					Adds info - sticky notes	date
FFP	2	a lot, after by rewriting	yes		often				yes		
FFP	3	usually doesn't take notes			no						
FFP	4	after rewrites groupping topics			yes						
FFP	5		yes		no						date
FFP	6	after rewrites into structured summary	yes		yes, not all		yes, after		yes		
FFP	7										
FFU	1	no, but uses colors, bullets	yes		no			yes			
FFU	2		yes								
FFU	3	no									
FFU	4		yes		sometimes						
FFU	5										
FFU	6	st. , highlites, reorders pages after	yes						yes	groups rel.info on pages (e.g adds to prev. pgs)	
FORM	1	no	yes		never					remembers format of notes - uses to locate them	order, format
FORM	2	no, uses colors, highlightes								takes notes on one page, page has structure	
FORM	3	yes, after takes imp. points, st. rewrites	yes		st.						
FORM	4	makes summaries	yes				yes				date&proj.
FORM	5	yes, while rewriting			some, imp.						
FORM	6		yes								
FORM	7										

Table 13: Main remarks (debriefing after the first session)

		Interview	Main remarks after 1st session			
Cond	#					
		Suggestions		Keywords - labels		Linking
FFP	1		prefers (he thinks) page titles to keyw.	keyw. useful to create links betw FFP objs		likes links betw FFP pgs
FFP	2	put rough notes after writing into forms		req,pat,param too abstract	too many tags/subtags	relations yes, but simple
FFP	3			more general heading/subheading		easier linking
FFP	4		moving objs. around to create all part pg	Wants to link obj in his own way. E.g req and req, req and act.		non-restricted linking
FFP	5		see all possible tags / links all the time	difficult to choose keywords		one general link
FFP	6		does not like adding page names after	difficult to add keyw, prefers own	diff. to differenciate keyw	relations hard to grasp
FFP	7	Multiple cols. for req/part/param with reminders	appearing for ea item.-also less pgs.		likes tags, because facilitate focusing on what's needed	
FFU	1			Keywords not easy.		
FFU	2			Likes keywords	Preselected keywords from domain (constr. parts..)	
FFU	3			Prefers page names to keywords.	Using page names to group.	
FFU	4	For this mtg. would take one pg of notes		Keyw good, but you can forget them	Groupping detailed keyw under main topics (projects)	
FFU	5					
FFU	6	Global numbering of keyw.		Keywords useful.		
FORM	1	Pre-set notes before meetings	Flexibility to design own forms	Main terms good, but fields too restricting	Generally forms good for note-taking	
FORM	2	Rather write all on one page		Selecting forms very difficult	Other fields even more diff.	
FORM	3	Info in forms too much broken apart, prefers one pg. Customize forms ind. terms.		Prefers specific pg titles to abstract terms	Not sure how to categorize	
FORM	4	Likes fields and predef. Forms -> doesn't miss anything. Getting used to forms-time.		Not enough time to categorize		Linking by pg# difficult - vis.
FORM	5			Normally, takes notes quickly -> changing forms, and deciding which form / field to use difficult		
FORM	6	One page better, no thinking where to put info.		"Other" category page useful.	Hard to decide which field.	
FORM	7			Not easy to decide which form to use. For example, req. vs. param		

Table 14: Main observations from the first session

Cond	#	Observations from 1st session
FFP	1	
FFP	2	Likes to have his pages clean. Applies tags/links meticulously.
FFP	3	Corrects "bad" handwriting. Would like to have the only possible relations added automatically.
FFP	4	Likes reasonably clean notes (del.accidental lines).
FFP	5	Rewrites first notes. Sometimes deletes and rewrites.
FFP	6	Rearranges objects on and betwFFP pgs. After applying keywords, goes through notes again to check what have she missed.
FFP	7	Uses some tags from a different perspective (his rather than project's).
FFU	1	
FFU	2	Often continues topic on the next page.
FFU	3	Goes back to previous pgs to add more to a topic (one of a few..) When new topic starts a new pg.
FFU	4	Wants to move words around. Not careful about selections.
FFU	5	(Eng.)
FFU	6	At the beg. adds 3 keywds. Likes neat->del. accidental lines, cor.unreadable letters. Careful about selections. Adds from mem, not q.cor.
		(cont.) At the end opened TOC to check if more keyw necessary.
FORM	1	Clarifies some meanings (param). TOC to navigate while note-taking. Puts multiple (sub-) topics in fields, order determines relations.
FORM	2	Not sure how to use forms. Puts everything in description. Often doesn't know where to put info. Many pgs contain the same pc.of info.
FORM	3	Less important writes wherever there's spot. St. puts unrealted info in one field. Important on separate forms. Likes forms in general...
FORM	4	Selectiing forms biggest problem. Choice changes! Some problems with consistant classific.-ambiguity or pers.usage. TOC navig.
FORM	5	(Eng.) Asks: what for pg name if each form has type? But does page naming in handwriting. Corrects notes. Descr form instead of Meet.
FORM	6	Puts unrelated info in one field. Often uses "descr" field only. Used gen."descr" form-didn't know which form or no waste time to select.
FORM	7	(Eng.) Created summary in point form using 3 meeting forms at the end (one req page in betwFFP). Used TOC to navigate.
		(cont.) why page names if form types? But perhaps would create them when reorganizing...

Table 15: Interview after the second session

Cond	#	Interview after 2nd session
FFP	1	
FFP	2	Terminology appropriate for large proj, for small overkill. When writing does not think in abstract terms of rationale, part, param, etc.
FFP	3	
FFP	4	Likes the TOC. Next time would add more keywords, also page title with more specific info.
FFP	5	Sug.specific section headings & group by them: "power supply", under: reqs, parts,. Would NOT use pg names->1 pg can contain many items.Name obj.yes
FFP	6	Keywords hard to use. Possibility of adding own. For example, "keypad", "power supply" and then adding info like "part", "action"->hierarchical struct.
FFP	7	Classification problems (was using s b.else's notes). Forms good for experienced person, multiple cols. for less exp.
FFU	1	Keywords unnatural. Normally would write keywords during writing, and find info based on visual scanning
FFU	2	Page titles more imp. than keywords. Would have used keywords better. Problem with (his own) overlapping ideas.
FFU	3	First uses page titles, than keywords if necessary.
FFU	4	No need to rewrite notes to org.-here can quickly add keyw.(& info) =saves time. Many proj.mtgs. specific keyw. group under main topic. Rearrange keyw.
FFU	5	
FFU	6	Would like to link keywords. Group rel. info by linking. Page names general, keyw good for details.
FORM	1	Did not use another meeting form for the scheduled mtg. 'coz no "future date" field. Used his diagram as "landmark" in notes correlating it to event dur. mtg.
FORM	2	Difficult to categorize. First writes then classifies (if necessary for a bigger project, this topic too small).
FORM	3	Now would use page titles.
FORM	4	Would use more pgs. Choosing forms biggest problem. Now would classify some info differently. Exp. helps. Would use pg titles. Forms diffic. for graphics.
FORM	5	Forms helped more than expected. Usually writes on one page, forms helped him organize info. In forms finding info quicker.
FORM	6	
FORM	7	Advatages for him: storing, editing, sending notes.

Table 16: Experiment note-taking (analysis of subjects' notes)

		Experiment Note-taking					
Cond	**#**	Dia-gram	Non-seq pages	%	Obvious no notes	N. import. no notes	Don't care
FFP	1	0			1	0	
FFP	2	0			1	0	
FFP	3	1			1		
FFP	4	1			1	0	
FFP	5	1			2	1	
FFP	6	1					
FFP	7	0				1	
		4					
FFU	1	1			1	1	
FFU	2	1					
FFU	3	1					
FFU	4	2			3	1	
FFU	5	0					10
FFU	6	1			1	2	
		6					
FORM	1	1	2	0.15	3	1	4
FORM	2						
FORM	3	0	2	0.18	1	1	
FORM	4	0	4	0.17			
FORM	5	0	1	0.05			
FORM	6						
FORM	7	1	3	0.18		4	
		2	2.4	0.15			

Table 17: Information organization in notes (analysis of subjects’ notes)

					Information Organization				**(out of page numbers - approx, or yes/no)**								
Cond	**#**	Pg 1-TOC home page	Page 1 main topic	Pg names (h/written)	Pg names (typed)	Summary pages	Multiple topics on pg	Subtit. for multi. topics	Group mtop by spacing	Grp mtop by lines	Moves objs to grp. related	Order of rel. info on a pg.	In-dents	Points, bullets	Lines arrow	Braces to grp	Cont. topic on next pg.
FFP	1	1	1	1	0		1	0	1	0			2	1	0	0	0
FFP	2	1	1	7	0		1	1	1	0			12	15	5	2	0
FFP	3	0	1	0	0		1	0	0	0			1	1	1	0	0
FFP	4	0	1	1	0		1	0	0	0			1	1	1	0	0
FFP	5	0	1	7	0		1	0	0	1			4	11	4	0	0
FFP	6	0	1	0	0		1	0	1	0	1		3	8	2	0	0
FFP	7	0	1	0	0		1	0	0	0	0		0	0	0	0	0
FFU	1	0	1	0	0		1	1	1	0			0	1	1	0	0
FFU	2	0	1	0	0		1	0	0	0			0	1	1	0	1
FFU	3	0	1	5	6		0	0	0	0			3	1	0	0	0
FFU	4	0	1	0	0		1	1	0	0			1	0	1	0	0
FFU	5	0	0	0	0		1	0	0	0			1	0	1	1	0
FFU	6	0	1	0	0		1	0	0	0			0	1	1	0	0
FORM	1	1	1	3	11		0	N/A	N/A	N/A	N/A	1		1	1	0	0
FORM	2			yes	yes, 10?		1	N/A	N/A	N/A	N/A						
FORM	3		1		0		1	N/A	N/A	N/A	N/A				0	0	0
FORM	4		1		0		0	N/A	N/A	N/A	N/A			1	1	0	0
FORM	5		0	19	1		0	N/A	N/A	N/A	N/A			0	0	0	0
FORM	6							N/A	N/A	N/A	N/A						
FORM	7				0	3		N/A	N/A	N/A	N/A		0	1	1	0	1

Table 18: Information retrieval strategies, part 1

					Information Search	(out of number of questions)									
Cond	**#**	**TOC->Page**	**TOC->tags->**	TOC->tags->	TOC->tags->	TOC->tags->sure/	TOC->tags->	Looking for	Additional	Avg. depth	Avg. depth	Following	Counting	**"Trust"**	**"Trust"**
		names-typed	**jump to pgs**	>1 tag tried	not->flip pgs	/more->flip pgs	follow link	a diff tag	tags check.	of tag.search	of search	**links** direct	tags	**strat.**	**strat.%**
FFP	1	0	3	1	0		0	0	0	1.33	1.33	0	0	3	0.19
FFP	2	0	9	1	1	1	2	0	1	1.22	1.56	3	1	12	0.75
FFP	3	0	12	1	1		2	2	0	1.25	1.50	0	0.5	12	0.75
FFP	4	0	3	2	0		0	0	1	2.00	2.00	0	0	3	0.19
FFP	5	0	12	2	0		0	2	1	1.42	1.42	0	0	12	0.75
FFP	6	0	14	6	0		0	2	3	1.79	1.79	0	0	14	0.88
FFP	7	0	7	0	0		0	3	0	1.43	1.43	0	0	7	0.44
										1.50	***1.60***			*9.33*	***0.58***
							N/A					N/A			
FFU	1	0	0		0								0	0	0.00
FFU	2	0	13	8	6	1		1	2	1.85	2.31		0	13	0.81
FFU	3	7	8	2	0	1		0	1	1.20	1.20		1	15	0.94
FFU	4	0	15	0	1			0	0	1.00	1.07		0	15	0.94
FFU	5	0	0		0								0	0	0.00
FFU	6	0	14	0	1			1	0	1.07	1.14		0	14	0.88
										1.28	***1.43***			***11.40***	***0.71***
							"link" can be								
							rel field cont					N/A			
FORM	1	11	2	1	1		0	0	1	1.15	1.23			13	0.81
FORM	2	0	15	7	0		0	0	3	1.67	1.67		1	15	0.94
FORM	3	0	8	4	0		0	0	2	1.75	1.75			8	0.50
FORM	4	0	15	4	0		1	0	3	1.47	1.53			15	0.94
FORM	5	0	16	8	0		1	0	4	1.75	1.81		1	16	1.00
FORM	6	0	15	8	0		0	0	7	2.00	2.00			15	0.94
FORM	7	0	1	0	0		0	0	0	1.00	1.00			1	0.06
										1.42	***1.47***			*10.60*	*0.66*

Table 19: Information retrieval strategies, part 2

Cond	#	Page 1-TOC =home pg	Page 1 main topic	Main topic topic tag	Main topic org. tag	Flipping pgs only	Flipping->F names-ha	TOC -quickly jump to page	"No trust" strategies	"No trust" strat. %	Other strategies	Other strat. %
		Information Search										
FFP	1	7	1			12	7	1	13	0.81	0	0.00
FFP	2	15	1			2	1	0	2	0.13	2	0.13
FFP	3	2	1			2	0	0	2	0.13	2	0.13
FFP	4	0	1			8	0	5	13	0.81	0	0.00
FFP	5	0	1			0	0	0	0	0.00	4	0.25
FFP	6		1			1	0		1	0.06	1	0.06
FFP	7		1			8	1		8	0.50	1	0.06
									5.17	***0.32***	***1.50***	***0.09***
FFU	1	0	1			15	0	0	15	0.94	1	0.06
FFU	2	0	1			2	0	0	2	0.13	1	0.06
FFU	3	0	0		1	1	0	0	1	0.06	0	0.00
FFU	4	0	0	1		1	0	0	1	0.06	0	0.00
FFU	5	0	0	0	0	14	0	1	15	0.94	1	0.06
FFU	6		1	0	0	0	0	0	0	0.00	2	0.13
									3.80	***0.24***	***0.80***	***0.05***
FORM	1	1	1			0			0	0.00	3	0.19
FORM	2		1			1		0	1	0.06	0	0.00
FORM	3		1			5			5	0.31	3	0.19
FORM	4		1						0	0.00	1	0.06
FORM	5		0			1			0	0.06	0	0.00
FORM	6		0						0	0.00	1	0.06
FORM	7		0			13			13	0.81	2	0.13
									3.60	***0.24***	***1.80***	***0.11***

Table 20: Information retrieval strategies, part 3

			Other strategies				
Cond	**#**	Summary pages	Switch 1st pg to check	Event sequence	Visual pg. memory	Land-marking	Check pgs around
FFP	1			0			0
FFP	2			0			0
FFP	3			5			1
FFP	4			0			0
FFP	5						
FFP	6			0			
FFP	7						
FFU	1						
FFU	2						
FFU	3						
FFU	4						
FFU	5						
FFU	6		1	2			
FORM	1			2		2	
FORM	2		1	1			
FORM	3			2	1		
FORM	4						
FORM	5		1		0		
FORM	6						
FORM	7	3					

Table 21: User label terminology usage, part 1

FFU Label Terminology Usage

Type	Ocurrences	Different terms	Different terms %	Label reuse ratio	Diff. abstract concepts	Diff. terms/ abstr.conc.
abstract	32	**12**	**29%**	**2.67**	9	**1.33**
concrete	40	**30**	**71%**	**1.33**	6	**5.00**
Total	72	42		1.71	15	2.80
Unused				1.67		
unused	6			0.33		
Total diff. Unused	6					

Project management terminology			Product structure terminology		
abstract	**concrete**	**concr %**	**abstract**	**concrete**	**concrete %**
2	**5**	***71%***	**2**	**20**	***91%***

Different abstract concepts

Predefined conce	Diff. terms	Ocurrence	abstract	concrete	Total
requirement	1	13	1		1
part	7	9	2	5	7
parameter	15	19		15	15
rationale	1	5	1		1
issue	0	0			0
action	7	12	2	5	7
meeting	1	1	1		1
Other concepts					
constraint	1	1	1		1
cost	2	2	1	1	2
feature	3	4		3	3
function	3	5	2	1	3
note organization	1	1	1		1
Total:	42	72	12	30	42

Table 22: User label terminology usage, part 2

Labels		Ocurrence	Abstract concept		
model	unused	0			
colours	concrete	1	parameter		
power	concrete	1	part		
functionalities	abstract	1	function		
keypad	concrete	1	part		
date	abstract	1	meeting		
diagram	unused	0			
backlit	concrete	1	feature		
PART	abstract	3	part		
type	unused	0			
material	concrete	1	parameter		
my task	concrete	4	action		
constr.	abstract	1	constraint		
review	unused	0			
del	unused	0			
start	unused	0			
temp	concrete	1	parameter		
device	abstract	1	part		
temperature	concrete	1	parameter		
functions	abstract	3	function		
dimensions	concrete	3	parameter		
introduction	abstract	1	note organization		
key spacing	concrete	2	feature		
cost (LCD)	concrete	1	cost		
colour	concrete	2	parameter		
battery	concrete	1	part		
material	concrete	1	parameter		
cost	abstract	1	cost		
scheduling	abstract	1	action		
period	concrete	1	parameter		
layout	concrete	1	feature		
keypad	concrete	1	part		
key size	concrete	1	parameter		
colour	concrete	1	parameter		
dimension	concrete	1	parameter		
temp range	concrete	2	parameter		
climate control	concrete	1	function		
depth	concrete	1	parameter		
material	concrete	1	parameter		
due in 1 week	concrete	1	action		
due in 2 weeks	concrete	1	action		
backup battery	concrete	1	part		
joe's work	concrete	2	action		
require	abstract	13	requirement		
job	abstract	1	action		
dim	concrete	1	parameter		
joejob	concrete	2	action		
reason	abstract	5	rationale		
Total:		72			

Table 23: User page name terminology usage

User Page Name Usage

	FFU	FORM	FFP	All
Total	6	12	0	18

Type	**Ocurrences (=diff.terms)**	**%**	**Diff. abstract concepts**		**Names/concepts**
abstract	**2**	**11%**	3		0.67
concrete	**16**	**89%**	6		2.67
Total	18		9		2.00

Project management terminology			**Product struct. terminology**		
abstract	**concrete**	**abs/concr**	**abstract**	**concrete**	**abs/con.**
2	**5**	***0.40***	**0**	**9**	***0.00***

Different abstract concepts

Predefined concepts	**Diff. terms**		**abstract**	**concrete**	**Total**
requirement	0				0
part	5			**5**	5
parameter	4			**4**	4
rationale	0				0
issue	0				0
action	4		**1**	**4**	5
meeting	2		**1**	1	2
Other concepts					
constraint	0				0
cost	0				0
feature	0				0
function	1			1	1
note-org	2		1	1	2
Total:	18		3	**16**	19

Page Names		**Concept**	**abstract**	**concrete**	**total**	**Labels used on page**
Introduction	abstract	note-org	1			introduction, temperature, dimensions
My jobs	concrete	action		1		functions, key spacing, cost(LCD)
Keys	concrete	part		1		dimensions, colour, key spacing
Power	concrete	part		1		battery
Casing	concrete	part		1		material, colour
Meeting	abstract	meeting	1			functions, cost, scheduling
						Type of form
design meeting missed	concrete	meeting		1		meeting
Dimensions	concrete	parameter		1		parameter
pre-set	concrete	function		1		requirement
temp-range	concrete	parameter		1		requirement
dimension2	concrete	parameter		1		parameter
functionkey	concrete	part		1		part
mytasks	concrete	action		1		issue
colour	concrete	parameter		1		issue
lcd	concrete	part		1		part
me	concrete	action		1		action
them	concrete	action		1		action
Rat.1	concrete	note-org		1		rationale
Total			**2**	**16**	**18**	

Appendix G

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