

Learnable Interfaces – Leveraging Navigation by Design

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ABSTRACT

Learnable Interfaces - Leveraging Navigation by Design

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Complex productivity applications that integrate tasks in the workplace are becoming more common. Usability typically focuses on short-term, immediate measures of task performance. This study incorporates a long-term goal of more durable learning, focusing on implicit learning (spontaneous, unplanned, usually unconscious learning as a result of other activities). It looks at how the design of complex applications can facilitate such incidental learning of both the application *and* the task domain when a conceptual model of the task domain is intentionally embedded. This can lead to more productive communication lower development and training costs, and improved task performance. The study targets the navigation interface as a gateway to exposing structural knowledge about the task domain as well as the organization of the application. Schema theory and cognitive load are discussed.

The study used an application developed to design and manage lessons in large training programs. The application reflected an explicit conceptual model of Instructional Systems Design (ISD). The experiment was conducted over the internet and exposed a range of users to application tasks using one of three. navigation interfaces. These menus reflected the underlying model to different degrees; content pages were the same. The pre-test assessed participants' understanding of the embedded model as a baseline. A series of typical application tasks ensured exposure to concepts. Performance and subjective data were collected to assist interpretation of results. The test, a multiple choice version of concept map assessment, was then repeated to show changes in model alignment.

Despite very brief contact time, the study confirmed that application interaction led to learning and greater alignment with the embedded model on all three measures: relationships, sequence, and vocabulary. Interaction was influenced by the cognitive load of high perceived difficulty and unfamiliarity and by the dominance of time spent on content pages over navigation time. Trends indicate a preference for constant menu visibility, familiarity, and simplicity (low informational density). Performance and learning for treatments reflecting the embedded model faired better than the standard Windows menu which shows only the application organization, not the embedded model.

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Mervyn Archdall, a Dublin pastor of the 1700s, said of his own work: "I have left that inaccurate which could not be exact, and that imperfect which cannot be completed."

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Chapter 1

INTRODUCTION

Motivation

Since technology became a pervasive force on the job and at home, perceptions of the role of the computer interface and its users have changed. The settings where digital supports are used have broadened dramatically; in the workplace especially, applications are increasingly critical and complex. This chapter explores these changing conditions to find areas where the design of such applications can lead to more durable learning of not only the application but also the domain it represents. Rather than and improve long-term job performance. This discussion provides the motivation for the current study.

It has been over two decades since computer use was the specialized domain of scientists, programmers, and data entry specialists; yet in practice the design of its user interface (UI) retains many characteristics and assumptions of its original use. The UI is the mechanism by which its user accesses the functionality of an application. Development of the application was the primary focus; users had to adapt to the tool. Depending on the complexity of the application and the job to be done, learning to use an application could take substantial effort.

Rather quickly, standard UI design approaches were developed to support less-expert users. For example, having to recall and type a particular command was replaced by menu lists of selectable features. The user interface became recognized as a critical component of user acceptance. Usability specialists were able to demand designs that focused on the abilities and preferences of the end-user rather than the developers. A subsequent emphasis on the contextual environment of users as members of teams and organizations extended usability concerns (e.g., Nardi, 1996; Winograd, 1995).

Over time the assumption that the interface had to be learned has moved toward a belief that the UI should be so simple to use as to be effortless. A commonly accepted interface (and instructional) design motto is KISS: “Keep it Simple, Stupid!”.

The much favored design concept 'intuitive' incorporates the senses of simple, fast, and unobtrusive, deriving (perhaps from the common use of intuition as 'gut-feeling') without thought or prior knowledge. The intuitive UI will be 'user-friendly': easy to use by the widest population possible – few errors, speedy and efficient with no thinking required.

Parallel to the goal of an intuitive interface is the invisible interface. Popular discussions of ubiquitous computing talk of the 'disappearing computer', that is, the expectation that technology would become invisibly embedded in everyday objects (see Streitz, 2008). The term quickly became applied to just the UI. The invisible interface is non-intrusive: so easy to perceive and employ that the user quickly becomes unaware of its presence and can instead focus directly on the computing goal at hand. Some have gone further to propose that the user shouldn't even have to look at the interface to use it (e.g., Nolker, 2010).

Such simplicity-oriented design goals are reflected in the heterogeneous collection of guidelines directed to programmers, web designers, analysts of web metrics, visual artists, instructional designers, and management – each interpreting them through very different lenses with differing immediate goals and addressing users with disparate levels of expertise. The simple, *intuitive* design approach with its goal of reducing attentiveness is widely assumed to result in less confusion and lower cognitive load¹, ergo usable interfaces. This need for familiarity (*intuitiveness*) leads to a concern for altering existing approaches too much and thereby conflicting with the user's prior learning of the application. This can make it more difficult to incorporate current research knowledge into designs.

Psychology defines intuition as the automatized, rapid, and unconscious decision-making by pattern-matching current situations to extensive past experience and knowledge. For example, Cavallin (2007) explores how precedent works in architectural design to influence unconscious conceptual models. This intuitive ability is a key characteristic of experts. Yet it is widely accepted that non-experts are the bulk of computer users. The increasing use of tools for information searches and

¹ Generally spoken of as requiring less thinking or effort.

social media, examples of comparatively simpler applications, set expectations that are unrealistic for more complex workplace applications. It is a worthwhile goal to reserve attention resources for the task rather than the tool² but studies indicate that complexity in the application and in task it performs will require more resources during performance until deeper learning occurs.

Simplifying the design of the interface works for uncomplicated applications or devices but a goal of simplicity and mismatched expectations for an intuitive approach are unrealistic for complex, enterprise-level applications. Not only is deeper domain-specific knowledge and skill required, cross-domain expertise is needed because enterprise applications are integrating tasks across more areas than ever before. Computer-based tasks typically require users to produce outputs that satisfy overlapping processes, contractual requirements, and distributed but interdependent decisions in the workplace.

Such expertise does not come without initial attention and effort. This suggests a rather different perspective on what is required to achieve an effective interface. Users have to expend substantial time and effort in learning to use such applications effectively; companies devote substantial resources to acquiring such applications, maintaining them, and training their workforce to use them as designed. Despite the rhetoric, learning is needed to interact with complex environments, physical or digital.

It is the premise of this dissertation that far from disappearing, the interface should be worthy of notice. It should encourage attention to the cues and structural information that the digital environment can provide about tool function as well as about the task domain. When these two foci are merged, such an interface can serve not only as a means of communicating commands to the application but also act as a collaborator whose design intentionally facilitates more durable, long-term learning. This shift would yield substantial benefits but requires an equally major shift in attitudes and beliefs about instruction and learning by the general populace.

It is not yet clear whether aids designed to scaffold unfamiliarity in an

² For example, when using a text editor, usability's goal is to have the writer's attention focused on what is being written rather than on which command to use to create a hanging indent.

application can potentially help equally with low domain expertise, but novices will require more scaffolding initially. Differences have yet to be investigated. As a target experimental population, novices who will encounter the most difficulty may be best able to expose relevant issues for further exploration. It is commonly understood that experts will want a quicker way to access functions, a more skeletal interface, but it remains important to ensure the presentation of consistent model when withdrawing no longer needed supports. Finding this balance for these types of complex applications needs more research attention as does the need for more fluid navigation than current approaches allow.

When looking for usability improvements, the underlying issue of what learning is taking place is often neglected in favor of shorter-term goals like error rates and speed (cf. Shneiderman's early proposals for menu selection above). When learning *is* considered in development and usability studies, the context is usually formal instruction or informal direction from colleagues. Most learning, however, takes place outside these settings. Concepts are unconsciously acquired and models built as a side effect of moving through the day-to-day environment.

There are fewer cues and orienting supports needed when interacting with simple interfaces like Google Search. The search box suggests it is appropriate to type in words; its length implies space for more than one word. When using more complex applications, the environmental cues become much more critical. Prior experience guides the perceptual interpretation of the ways controls are grouped and sequenced, how items are organized in menus and help systems, what is the same and what is different, what is larger and what is smaller, what is repetitive and common, and what is not. When trying to complete a task or simply exploring, this information is building a model that is used to predict and choose responses. That model is largely unconscious and can vary widely between individuals. Finding a practical design approach that integrates relevant research is an area that needs more attention. One promising approach is to extend the role of the application beyond that of a tool for task performance to include the knowledge domain and to explicitly design complex applications to encourage learning, both incidental and

intentional.

In the workplace, it is desirable to have a shared understanding of tasks that leads to a predictable, uniform outcome. Employees will arrive on the job with diverse conceptual models of the job that reflects their individual experiences, skill levels, and expectations. Each person may use only a portion of an application and for different purposes. For example, one person might be responsible only for entering a single type of data such as components, into the application, requiring only familiarity with source materials. Another might perform task analyses which require deeper categorization and technical expertise. An artist might manage the media libraries. A manager will be interested in the reports. Those creating products using the tool will need to use the widest range of functions. All will need to comprehend the overall structure and sequence since it reflects management decisions and goals. They will be novices in terms of application expertise and will need support if they are to become more uniformly proficient.

Explicit instruction is intended to support a more homogenous approach but experience shows that it is often not scheduled as early as needed. User misconceptions acquired before such training can be difficult to remove. If the model the application exposes is intentionally designed to support conceptual model building, the application itself can encourage movement toward alignment, there may be fewer misconceptions to correct, and explicit instruction can be more effective. When training stays consistent with the design intention, the conceptual model can more readily be made conscious and therefore a tool for decision-making, a basis for communication.

Psychology has a long and active history of investigating the formation of conceptual models. Much of this drives the guidelines for interface design. In 1987, Ben Shneiderman suggested research directions for human computer interaction that included:

- reducing anxiety and fear of computer usage,
- menu selection (in terms of content, number, placement, and phrasing),
- response time, display rates, and operator productivity, and

- graceful evolution (supporting the transition from novice or intermittent user toward more expert use).

Shneiderman's questions continue to be valid. As the pace of technological changes and knowledge of human cognition deepens, these issues need to be revisited regularly. Applications, particularly in the workplace, are becoming more complex as they try to integrate information and processes from disparate areas.

While computer use has become ubiquitous in the intervening years, most people still use simpler applications (by today's standards). Most are no longer intimidated by computers but unfamiliarity with new design techniques or types of applications can still cause enough anxiety to interfere with performance. Menu selection research has evolved beyond strictly quantitative measures but interface designers often leave behind earlier lessons learned as irrelevant to the newer design trends. The design of menus, now more broadly referred to as the navigation interface, has moved into a deeper investigation of spatial cognition to guide design options in more popular areas like 3D and virtual environments. With technology improvements, highly visual presentation and interaction techniques have been explored and tested. The move toward graphical interfaces (e.g., Shneiderman & Maes, 1997), led to an early 2D visual interface used to navigate to flightline locations and interact with items in a computer-base learning system (Swanson, 1995) and later full 3D projects like Virtual Puget Sound (Winn et al., 2006). These more visually rich environments provide an opportunity to support increasing expertise but are still uncommon outside of gaming and simulations for critical systems like aviation and nuclear energy. The development costs are high, there are fewer precedents to rely on since examples are often proprietary with limited access, and interdisciplinary teams with sufficiently broad expertise are difficult to find and coordinate. Without more guidance using more accessible language to interpret it by everyday practitioners, it can be difficult to transfer lessons learned from very specialized research applications.

Less complex uses could be expected from these visualization advances but remain uncommon outside of game environments. (Gaming uses them primarily as

geographic maps.) Concept maps have been discussed and used for navigation in many research projects, generally focused on information search, but this approach is hard to find in regular use. (e.g., Amadiou, Tricot, & Marinéa, 2010; Cañas et al., 2005; Tergan & Keller, 2005;) Uses that are seen typically use concept maps as a slightly more visual way of presenting an otherwise traditional, hierarchically arranged, list of topics. Visual concept maps have been shown to have the potential to expose the underlying conceptual structure of a domain but the focus on exposing a conceptual model of an application's task domain for navigation purposes is still largely overlooked by interaction designers. Don Clark's website (Appendix J) is a rare example of navigation using a concept map but the map is not consistently available and is secondary to more conventional menus.

There have been many attempts to support the growth of expertise by other forms of embedded assistance but few have made it into common usage. Most help systems still focus on tool use, not the user's cognitive skills. Vouligny (2005) characterizes the most common forms of assistance as information about system function, typical tasks, and frequent problems (FAQs). Approaches to online assistance include the infamous Clippy, incorporating web resources, adaptable menus (Findlater, 2004; McGrenere, Baecker, & Booth, 2007), varying approaches to traditional help system design (Vouligny & Robert, 2005; Willis, 2006), on-demand web assistants (Aleven et al., 2003), visual filtering methods for large datasets (Heer, Card, & Landay, 2005), and other intelligent agents.

This research suggests adjustments to the design of the human interface to better address how to support acquisition of a relevant conceptual model. It addresses more explicit instructional settings such as classrooms and help systems. It more often targets applications used to manage large information stores such as digital libraries and online searches. What is missing from this research is a clearer answer as to whether and how these results apply to other uses such as complex, production-oriented applications. All will be novices in tool use initially but bring different expectations and skills to this experience. Efforts to accommodate differing expertise levels must address not just user experience with similar, complex

applications, but also the level of user expertise in each of the task domains for which the application is used.

The question that needs a better answer is whether current guidelines are sufficient when looking at both tool use and concept formation together. Research and usability studies both need to more fully integrate how interface design affects the formation of a richer conceptual model of the task domain with the well-travelled focus on tool use. Systems theory suggests that looking separately at each area may not be the same as looking at them together. Before continuing to look at narrowly defined issues within carefully controlled experimentation, it seems productive to look more broadly at the limitations and issues to be solved under more ecologically valid conditions. Can the interface act as an implicit instructor and collaborator? If so, ease of use and more efficient performance will follow.

Questions & Scope

Questions of interest in this study are based on the extent to which an explicit mental model can be embedded in an interface and - through unguided interaction - facilitate formation, adjustment, and application of a user schema³ aligned with the designed structure. Following Kerr's (1990) question, still not investigated to my knowledge, can one *supply* a mental model and how will that affect a person's existing model? Does it depend on the quality (level of expertise reflected) of an existing user schema? Can the presence of highly consistent vocabulary influence a preference for using those word choices, replacing previously acquired terminology and thus improve communication in the workplace? What are the encoding mechanisms and how can they be leveraged by design? What are the limitations of implicit learning in a authentic context, outside the laboratory and with real, complex tasks rather than artificial constructs? Can causal effects be separated from correlated effects sufficiently to show a significant result under such uncontrolled circumstances? What guidelines can be developed with enough specificity to apply readily and still be general enough to use in a broader context?

³ See Glossary: *Schema*. Schemata was commonly used as the plural form and continues to be by some researchers but in more recent research "schemas" is usual.

This study is intended to encourage further exploration into such questions. It is necessarily exploratory in nature and addresses the most general questions, in order to prepare for more targeted studies in the future. The figure below introduces the context of this study, the outer ring: implicit learning in informal settings - where most learning takes place but is the least well understood.

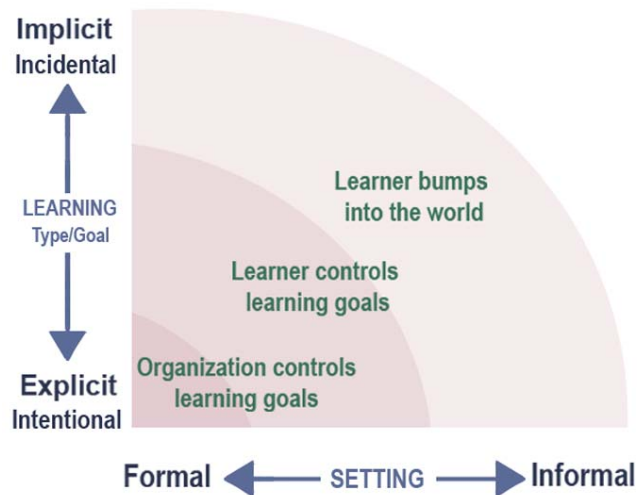


Figure 1. Dimensions of learning. Study context.

Applying a design perspective, this study explores the incidental learning that can occur through untrained exposure to more complex, process-oriented workplace applications. It proposes a focus on learnability, based on the embedded design of an explicitly defined structural model containing both novel concepts and relationships. Such an approach can affect both usability and long-term domain knowledge. Because there is little or no specific precedent for conditions present in this experiment, this study is also intended to explore what issues are most relevant for future research in this context.

Most prior research in areas relevant to this study has been conducted in instructional settings. This study focuses only on the incidental, implicit learning of the two primary components of conceptual models, relationships and sequence, that takes place without explicit instruction. Aiding materials refer only to the operation of the application and do not provide information about the conceptual structure.

Complex, task-oriented applications are common in large enterprises and

represent the type of interaction that places additional burdens on cognitive resources as well as training budgets. This challenge still needs better solutions. The application, ISD WorkSpaces, meets the criteria for an integrated, complex workplace application. It is based on a content-development/curriculum management tool developed for the US Air Force and used under contract for many years. It is used to identify, categorize, and prioritize tasks that require learning (Task Analysis). Those results are used to define how the tasks are best taught (scenarios, cues, conditions, and standards for assessment) and what resources are required (Learning Analysis). These skill and knowledge objectives are grouped, sequenced, organized into instructional units, and scheduled to define curriculums for multiple populations (Curriculum Planning). Progressively more detailed design documents can be produced as needed (e.g., outlines, storyboards, and scripts) depending on the strategy and media selected (e.g., self-paced computer-based lessons, lecture, simulator practice, online discussions); required media is specified (Design phase). Production (including media libraries) and assessments are then supported. Maintenance functions allow for learning strategies, resources, processes, and document formats to be embedded. Traceability and accountability is maintained throughout. Applications of similar complexity may be found in controls for critical systems like nuclear power plants and submarines, in managing online advertising, and more integrated human resource applications.

The idea of defining a schema is now common in computer science as a way to identify and structure tasks but these do not always coherently and faithfully represent the application's focal domain. While a user will develop a conceptual model of the application through use, it may not match the designed model. This can limit the user's ability to become a more expert user of the tool. Prior research also suggests that if the application does not represent the domain of use or directly conflicts with norms, the novice user may become a proficient user for familiar tasks but will be less flexible. The more expert user may find learning the tool more difficult.

This study limits issues of conflicts between application and domain models. It uses an application whose embedded model faithfully represents its focal domain.

Users of enterprise-level tools typically reflect a diversity of ages and experience so a population of adult users is targeted with no restrictions on participation. Domain expertise is assessed to determine whether there is a possible conceptual conflict between the participant's structural model based on prior domain experience and the application's model of the domain it represents.

The time frame is limited to brief, initial exposure to determine whether structural aspects of the application and domain can be acquired and to what extent this is mediated by the design. Longer term studies are needed to assess how durable the initial learning is.

Navigation is expected to provide the most immediately accessible view of the embedded model. The navigation can only be artificially separated from the page content; so both are presented together for maximum realism. The tasks represent common activities in the represented domain, instruction systems development. Scenarios provide job context. The participant is asked to take the role of a new-hire that needs to check what tasks have been completed prior to continuing lesson that was partially completed by a former employee. This person must find the pages that show specific data, such as a component, a learning objective, a topic in a lesson outline. (Selections are required but not data entry.) The navigation activities should amplify any conceptual influence of the content pages.

Research Hypotheses

The following hypotheses will be investigated.

H1. Under conditions of open, unguided interaction and when the navigation interface is designed to visibly reflect an explicit structural model of the underlying task domain, it is predicted that the designed model will implicitly influence a user's schema of the task domain by moving it toward alignment with the model in the software.

H2. It is predicted that task performance will be improved by a navigation interface design based on an explicit model that reflects an expert view of the domain (both WEB and MAP versions) and that this effect will be stronger for users with less instructional experience.

Open, unguided interaction is defined as open access to all navigation paths at any time in any sequence and that navigation is undirected, without aids other than those built into the application. Aids that are part of the task forms are present for all participants regardless of navigation interface type and are expected to reduce differential performance effects but are necessary to use the application without prior training. The navigation interfaces vary in level of support available as described under the Materials section.

H3. The designed model is referenced by a vocabulary. When a controlled and consistent vocabulary is used throughout the task environment, a user is predicted to exhibit a deeper semantic connection between those terms and associated system functions and domain concepts than a user who is not exposed to a consistent terminology (vocabulary alignment).

H4. Many models of instructional development exist which can conflict to varying degrees with the designed model. A user with a more specific schema of instructional development, as evidenced by prior experience in the task domain, is predicted to demonstrate less structural schema alignment and vocabulary alignment than users with little or no experience.

H5. Both the MAP and WEB versions represent the same domain model. The MAP version has expanded spatial imagery and relationship information that is predicted to show improved route efficiency. The MAP navigation interface is also predicted to show the greatest level of structural and vocabulary alignment; the WIN version with its topical organization the least.

H6. Users are predicted to rate visibility of the navigation interface as a preferred feature.⁴

Organization of the Dissertation

In the first section of this chapter I reviewed the current state of interface

⁴ Visibility is a relative term. Hypertext where navigation controls only become highlighted on hover are an example of a more invisible menu as are systems that move you through a program automatically based on your choices or actions. Very visible menus show all navigation options at all times. These are typically those with fewer destinations. A combination of visible and temporarily hidden options are most common, such as selecting a tab which then shows a second row of tabs.

design to suggest a need for expanding design goals in another direction, to consider the learnability of underlying knowledge structures rather than continuing to focus only on the use of tool features. More durable, long-term learnability does not yet appear to be designed into applications in current use, suggesting there are many questions that are yet to be answered. I then identified which of these this dissertation will address.

The next chapter provides the theoretical foundation for the study. Schema theory provides a firm psychological account of the structure of acquired knowledge and its interaction during the encoding process. The hypotheses for this study are based on the ability of the interface to facilitate formation, adjustment, and application of schema aligned with the designed structure. A discussion of the limitations, constraints, and interferences that encoding is susceptible to previews design considerations for the study.

Additional processing burdens are expected in complex environments. Cognitive Load theory provided guidelines for the design of both navigation and page content. It offers an informative perspective when interpreting the study results. The conceptual barrier of inconsistent vocabulary use is addressed as a possible inhibitor of schema formation and a source of additional load and conceptual confusion.

The substantial research on navigation in physical space and electronic environments is widely accepted as compatible, with electronic spaces having additional flexibility; this is reviewed as justification for choosing a spatial representation as one of the interface versions in the study.

Concept mapping offers a way to externally represent and assess structural knowledge acquired during incidental learning. It is also basis for the design of one of the menu treatments, MAP. Systematic instructional design techniques are discussed as an example of a structural model for an application interface. The model embedded in the application used in this study reflects a common Instructional Systems approach.

Chapter 3 is the Methods chapter and describes participant selection, the experimental design, the software application used to perform the tasks, supporting

materials, and the procedure to be implemented. The final chapters present and discuss the findings. Chapter 4 concludes this discussion with the contributions this dissertation offers and a path for future research.

Glossary Support

The foundation for this study draws on research from multiple disciplines, theories, and approaches, often with different vocabulary for similar concepts. As these can only be partially and briefly referenced in this dissertation, the glossary provides additional orienting information. Many of the concepts are still controversial or used with divergent meanings. The glossary therefore also presents definitions for terms as used in this study with references to alternate terms and related concepts.

In particular the phrase "incidental learning" is used broadly here to indicate conceptual change where learning is not the primary goal of the person but is the side effect of another activity such as using an application to perform tasks. Unlike the concept of "implicit learning", its use here is not intended to carry assumptions about conscious direction, unconscious or precognitive processing, activation of prior knowledge, or attentiveness or lack thereof.

This dissertation also uses "conceptual model" as a general term describing a mental construct that relates and organizes knowledge into a pattern of interdependent associations that is sufficient to guide expectations and decision-making. Its use here is to reference the commonly accepted, shared characteristics of related terms without addressing distinctions made. These terms include Schema (including subdivisions like relational and prototype schemas), Mental Model, Knowledge Structure, Conceptual or Cognitive Maps, Cognitive Model, Semantic Network, Scripts, Cognitive Architecture, Cognitive Collage, Cognitive Framework, Construct, Frame, and Working Model.

Chapter 2

LITERATURE REVIEW

The premise of this dissertation is that interface design can and should focus more broadly on what type of learning is taking place and whether interactions supplement or hinder the formation of more productive conceptual models. To better understand how to integrate learning into the user experience, we have to look beyond concerns of immediate performance. Learning is conceptual change - the creation, retention, and retrieval of memory traces that together form knowledge. Schema theory from a spreading activation perspective provides a useful starting point to investigate how best to facilitate this change, with a specific focus on the relational and sequential aspects of structural knowledge.

Most learning is incidental, a by-product of another activity rather than an intentional, goal directed effort to learn new information. For example, children learn that birds fly and worms do not without their parents telling them and long before they begin school. They may notice a relationship between these two concepts, that birds eat worms. This study investigates to what extent such structural knowledge can also be acquired through exposure to an application interface *without* explicit instruction. Research in incidental learning within the framework of schema theory can inform design. The variation in terms related to distinctions of less attended learning is particularly apparent in this area of research. In this study incidental learning is viewed as a continuum from implicit to fully explicit, not as two separable processes. Commonalities are addressed.

The navigation interface tends to be the first and most continuously present feature of a screen. It typically represents categorized knowledge and can be adjusted to reflect an underlying conceptual model. It is therefore seen as the most likely part of an application to influence schema induction under incidental conditions. Guidance from navigation theories of the physical world apply to navigation in electronic spaces with some accommodation for the different instantiations of

features like signposts, landmarks, and routes. Theories of spatial cognition⁵ are relevant but assessing skills and their effects on performance are outside the scope of this dissertation.

As complexity increases, processing burdens increase, especially for intermittent users and those new to an application. Users may be expert tool users but have inaccurate or inadequate models of the domain of use. Domain experts may have a rich but conflicting schema that impacts tool performance. Cognitive Load Theory (CLT) provides some direction about how to relieve such information overload although most research here relates to explicit instruction and information searches online. Theories of expertise will not be addressed in detail since the study application will be new for all participants.

This chapter concludes with an discussion of Concept Maps as a method to elicit and assess structural knowledge in the context of incidental learning. Concept Map research guided both the design of the third menu treatment, MAP, and the variant text-based method of capturing and assessing changes in user's structural knowledge.

Schema Theory

Frederick Bartlett introduced the concept of schemas as part of his theory of learning and it has influenced every facet of psychology since. The term is used extensively but inconsistently in cognitive and social psychology to refer to a flexible, cognitive pattern of related concepts and actions that develops over time as we interact with the world. This network of associations is both a psychological description of how memory is organized and a physical description of brain function. Norman, Gentner and Stevens (1976) have described the organization of schemas as a network of nodes and links (relationships), a vocabulary that reflects a computational approach to memory.⁶

The initial stage of encoding is brief, transient, and has very limited memory capacity available for processing. For example, we can remember no more than

⁵ See Glossary: *Spatial memory & cognition*

⁶ See Glossary: *Semantic network*.

approximately seven serially presented random numbers (Miller, 1956) for no longer than several seconds (Peterson & Peterson, 1959), unless the numbers are intentionally rehearsed (Kalyuga, 2006) or have semantic representations and can be chunked into meaning units⁷. This limited capacity especially impacts learning of unfamiliar information or processes. Category learning⁸ is a fundamental feature of cognition and a prerequisite of schema formation. Learning to distinguish membership requires a variety of examples (e.g., Bruner, 1967; Medin, 1997; Chi, 1981; Estes, 1994) to enhance or inhibit activation but theories diverge on the process.⁹ Similarity to previously learned information helps categorization but retrieval is prone to distortion and error. One recalls a reconstruction, not a snapshot.¹⁰ Schacter (1998) emphasizes that the initial binding of features of an episode together as a coherent trace needs to have sufficient pattern separation from similar episodes. Factors such as repetition, elaboration, and prior knowledge increase the strength of these neural patterns and thereby increase the probability that the pattern will be stored long-term as a coherent memory trace. Since people are more likely to notice things that fit into their existing schemas, there is a tendency for patterns to remain unchanged, even in the face of contradictory information.

Concepts have limited meaning unless the relationships between them are defined. This structural knowledge is fundamental to schema. When encountering a problem that needs a solution, what is retrieved is influenced by prior experience. A person looks for perceived similarities, attempting to make generalizations about

⁷ Berninger, V. B. (personal communication, May 20, 2012): The classic claim of 7 plus or minus 2 applies to short term memory which occurs on a time scale in milliseconds at the neuronal level. Kandel got a Nobel prize for seminal work showing this. Working memory where goal-related processing takes place can draw on both short-term memory and long-term memory representations. It has the capacity, resources, and timing limitations but is not the same as short-term memory.

⁸ See Glossary: *Category learning*.

⁹ For example, identification of prototypes, perceptual features (surface similarities), progressive generalization, or probability assessment.

¹⁰ Berninger, V. B. (personal communication, May 20, 2012): unless the representations are accessed through subcortical caudate/basal ganglia networks (automatic S-S or S-R associations). Constructive processes occur in tertiary cortical areas (very abstract) but can be influenced by pathways to and from the subcortical limbic system (emotional brain).

category membership and the relationships between them. These analogies map a current experience to existing conceptual models on the basis of such structural correspondences (Gentner, 1983; Holland, Holyoak, Nisbett, & Thagard, 1996). As Newlon et al (2008) describes it, the individual: 1) builds a system of analogies¹¹—a description of subjective entities and the relations among them and 2) uses the model to imagine alternative courses of action, to assess the imagined outcomes of each, and to select the best one.

Spreading activation¹², first proposed by Anderson in 1976 (see Anderson, 1983) and since modified and extended several times, describes the propagation patterns that are the basis of relationships.¹³ Spreading activation theories are usually interpreted as predicting that more activated structures will receive more favorable processing (Pirulli, 1997). Activity in working memory activates traces in long-term memory to be processed together based on the associative strengths of each element, that is, the activation of any given element spreads to neighboring elements, with the breadth of the activation based on strength of the activation, level of association, or perception of relatedness. It accounts for the strong effect of prior knowledge as well as context effects of environmental and task on schema induction. In Anderson's account the tight associations of schema become more dense as new information is accreted.¹⁴ This density allows for more complex sets of associated chunks of information to be retrieved and manipulated - a characteristic of increasing expertise as is the quality of this composite set. Traces are assumed to be retained but the strength of the trace may decay from disuse or structural modification (e.g., conflict, emotional response), affecting retrieval.

Models can contain visio-spatial, semantic, time-related, and procedural components. They are thought to be constructed through the interaction of the visual

¹¹ See Glossary: *Analogy, Analogical reasoning*.

¹² See Glossary: *Spreading activation, Fan effect, Hopfield networks*.

¹³ Spreading activation as a cognitive representation and physical description of neural activity can reasonably describe schema and category/analogical learning although it is not commonly applied to to discussions in the latter contexts.

¹⁴ See Glossary: *Chunking*. Reference Miller's 1956 paper on limits on information processing capacity.

and verbal systems in working memory (Schnitz, 2002). They also contain routines, how to get things done and can be used to mentally run simulations to predict outcomes based on prior experience. Schemas or mental models¹⁵ are characterized by internal consistency and identifiable referents that are meaningful in the contexts¹⁶ in which they occur. Context affects judgments of similarity. Concepts acquired in a one context can remain dependent on that context, not readily perceived as analogous to a similar set of conditions, thus not retrieved or applied in other problem solving situations (e.g., Crews, 1997). Context can be formed around spatial and temporal features. Both features determine whether associations are formed (e.g., Howard et al, 2009). The richer the model, the more experiences it reflects, the more helpful it is in dealing with uncertainty and complexity in a specific domain.

When information or experience conflicts with an existing schema or strongly-held belief, conceptual confusion and cognitive dissonance occur. Conflicts interfere with attention, therefore processing efficiency, and increase cognitive load.¹⁷ There is a preference for resolving this conflict¹⁸. One can ignore it if possible, rationalize or redefine it such that is no longer perceived as a conflict, or deny the validity of the evidence. Theories are less uniform in their specific attribution of cause and related processing mechanisms.

Schemas guide attention¹⁹. They are conservative by nature; features not recognized as important will be ignored (e.g., Dreisbach & Haider, 2009)²⁰. Interaction with the perceptual and sensory inputs that are present in environments, both physical and electronic, can be implicit (automatic, without awareness) but may require attentional resources. Attention is naturally selective, attempting to reduce

¹⁵ See Glossary: *Schema, Mental models*. Mental models are sometimes differentiated from schemas as being more procedurally and goal oriented whereas schema research focuses on memory processes.

¹⁶ See Glossary: *Context, Contextual Cueing, Encoding Specificity Principle, Spatial memory & cognition, Navigation Aids*.

¹⁷ Refer to the section on Cognitive Load Theory, this chapter; see also the Glossary.

¹⁸ See Glossary: *Accommodation vs. Assimilation*

¹⁹ See Glossary: *Attention/Awareness*,

²⁰ There is evidence that even peripheral features are attended to and processed although the person may not recall being aware of a stimulus.

irrelevant inputs and processing load²¹. For example, Jiang & Chun (2001) applied a contextual cueing paradigm to look at the effect of selective attention. When the spatial configuration of items in the attended color was consistently paired with a target location, visual search was facilitated, showing contextual cueing whereas pairing the attended pattern with an unattended color produced no cueing effect. Under conditions of cognitive load and time pressure, attention will be further restricted and even relevant traces may not be activated.

Cues facilitate both recall and interpretation of available schemas during task performance, especially in complex learning environments, and the construction of new schemas (e.g., Hummel & Nadolski, 2002, Lee (2007)). Cues form context. Context of acquisition is a highly influential factor on schema formation. Concepts acquired in a one context can remain dependent on that context (e.g., Godden & Baddeley, 1975, 1980; Crews, 1997). Environmental cues are influenced by perceptual cues encoded with learned concepts. Cues implanted in the interface are therefore an important tool for designers; they can help beginning or infrequent task performers identify attention-worthy elements and enhance learning. Consistency (environmental regularities) and saliency will affect whether cues are noticed, how fast they are processed, and how they are interpreted. Novel or changing elements degrade speed (e.g., Chun & Jiang, 1998; Findlater & McGrenere, 2010).²²

Repetition and practice matter for schema building: facts studied more frequently are recognized faster (Anderson, 1983). By itself these lead to proficiency over time but do not ensure mastery. Innate factors like talent and age cannot be changed by training (Ericsson et al., 2006, p.683).²³ Variation, especially in context, is also important to build more highly integrated sets of associations and variability also aids retrieval (e.g., Gobet, 2005). One area where variation is a detriment, especially for novices, is terminology inconsistencies. Multiple vocabularies and

²¹ Dreisbach & Haider (2009) propose a 'global shielding mechanism' to supplement models of selective attention.

²² See Findlater & McGrenere (2010) for a discussion of consistency effects on awareness.

²³ Clearly, however, innate talent can be enhanced by environmental factors such as the presence of encouragement, opportunity, and training whether the area of talent is emotional, physical, or intellectual.

dictionaries present a cognitive challenge to recognizing conceptual similarities. Rather than grouping equivalent concepts together to enhance an existing schema, they are often viewed as distinct and unrelated. When stored separately, additional memory is required to process and use them; separate retrieval cues will be required to activate each schema. These vocabulary differences affect not only schema formation but are an impediment to the interdisciplinary approach necessary for the design of a more conceptually-oriented interface.

Retrieval is sensitive to those association strengths set by initial encoding and subsequent recoding. Although it may be retained, it may not be reliably or appropriately retained (inert knowledge). Anchored instruction²⁴, influenced by situated cognition frameworks, addresses this issue, stressing the importance of presenting opportunities to discover not just the 'what', but also the 'when' and 'why' the knowledge should be applied (CTVG, 1990; Crews et al., 1997).

Experts' mental models are domain-specific, rich, highly chunked, representations of how things work.²⁵ Experts rely on contextual cues to activate appropriate schemas (e.g., Ericsson, 2006). As structures grow, processing becomes more automated and tacit; experts are less able to articulate their reasoning. Their models reflect substantial domain knowledge which allows them to more rapidly categorize incoming information. They integrate function and structure to assess relevant features and solve problems. This foundation also facilitates further domain learning. In contrast novice models show a paucity of interconnected knowledge and chunking; they typically encode mostly surface features. They also tend to form mental models of structure separate from the knowledge of function. (cf. Ericsson, 2006; Heiser, Tversky, et al., 2003; Hegarty, 2004; Trumbo, 2006).

Teaching research focuses on explicit attempts to induce schema formation or

²⁴ See Glossary: *Anchored instruction, Situated learning, Action learning, Problem-based learning, Retrieval.*

²⁵ Chunks are sets of interrelated information that accrete (can be made up of smaller chunks) and are retrieved as though they are single items. The *Cambridge handbook of expertise and expert performance* (2006) is an excellent overview of research of expertise. It covers history, methods for studying structure and acquisition in a variety of contexts, and specific issues affecting expertise such as attention and aging.

modify it. The Piagetian concept of *assimilation* describes the process where new information is incorporated into an existing schema without changing it.²⁶

Accommodation occurs when new learning conflicts with an existing schema. Either the schema must change to accommodate the new experience, the information must be redefined, or the information must be discarded.²⁷ Much of the guidance obtained from explicit instruction settings can also be useful for designing interfaces and constructing online tasks such that they support incidental learning. Using this research requires attention to assumptions that may fail to differentiate between theories of memory and learning from theories of pedagogy (Schwartz, Brophy, Lin, & Bransford, 1999).

An example, the Cognitive Apprenticeship learning theory based on the master-apprentice model, seems particularly relevant to embedding a learning perspective in applications. It emphasizes the importance of implicit knowledge gained through interactions and the process of then making it explicit such that it can be applied intentionally. This theory proposes 3 stages: acquisition of declarative knowledge of a skill (cognitive stage), corrections of misconceptions and strengthening understanding of relationships (associative stage), and automatization of these processes (expert stage). This dissertation proposes that an appropriately designed application can take the role of master in a cognitive apprenticeship. The basic conceptual information is acquired through implicit modeling. It is preparatory for more explicit instruction where it can be made conscious and intentionally applied.

Deductive teaching²⁸ is generally preferred in workplace training settings. Initial principles or goals are stated first (the big picture) and then knowledge is built to support those in a building block approach, moving from simple to complex. Prince (2006) describes this method as typical of engineering and science where the student is expected to absorb knowledge presented rather than construct their own

²⁶ This is due either because it is perceived as a 'good-fit' through an analogical process (which is error-prone) or because the schema is insufficient to determine similarity accurately.

²⁷ See Glossary: *Interference effects*.

²⁸ See Glossary: *Deductive Teaching*

understanding of it in contradiction of constructivist²⁹ principles. He sees an externally supplied conceptual model as lacking perceived relevance on the part of learners, reducing motivation to learn in contrast to an inductive teaching approach. This is an unnecessarily narrow view; the two perspectives need not be mutually exclusive. In art training where individual creativity is highly prized, for example, it is common to require students to copy the styles of earlier masters before embarking on their own paths. Most educational efforts similarly require students to learn about what is collectively known about a subject area before embarking on a career path or initiating new research. This is generally assumed to have taken place before one is hired, particularly in the sciences, but is not as common in the training field where prior experience is expected but not pedagogical training.

Kerr (1990) extends the discussion of the importance of a structural mental model beyond the classroom, highlighting its role in navigation through electronic environments generally. However he suggests that it isn't always best to train to induce a specific model, that people differ in their ability to form appropriate models for themselves, and that existing models can conflict with presented models. Kerr's paper suggests that supplying a target model may be best when the user is less likely to form an efficient model independently, such as in an unfamiliar, complex, highly unstructured environment, or where workplace goals require adoption of a specific model. In a related experiment using Cognitive Toolboxes, Mathews, (2001) found that memory of the knowledge facets (tools) was equivalent whether students developed their own organizational scheme or used the one provided by the course instructor.

This difference in approach is a long-standing point of contention between teaching in educational settings and training in workplace settings. It may arise out of earlier behaviorist approaches, still favored by enterprise training departments, that imply that the learner absorbs presented knowledge indiscriminately and that this interferes with formation of a more personally relevant schema. However, modeling a desirable schema can only influence existing conceptual models, an outcome at the

²⁹ See Glossary: *Constructivism*

foundation of any instructional act. Providing a clear example for early and intermittent users acts as a scaffold, promotes helpful social communication, and potentially offers a varied perspective that can enrich the expert's existing understanding. The current study assumes the basic value of a cognitive apprenticeship and expands this focus to investigate whether an externally provided conceptual model can be induced implicitly and if so, will the user's model align with the provided one.

Incidental/Implicit Learning

The 1990's brought a renewed interest in an old topic, implicit learning. Terminology for this area of theory-making and research has proliferated; different, often conflicting definitions affected the emphasis placed on different aspects.³⁰ Terms like incidental learning may refer to the learning setting (informal vs. formal learning) or learning goal (side effect vs. intentional learning). Marsick and Watkins (2001) define it by its contrast to formal learning with its highly structured, controlled learning. Although sometimes used interchangeably with informal learning³¹, they state: "Incidental learning is defined as a byproduct of some other activity, such as task accomplishment, interpersonal interaction, sensing the organizational culture, trial-and-error experimentation, or even formal learning." Incidental learning is almost always taking place, even when the learners are not aware of it (Marsick and Watkins, 1990, p. 12).³²

Reber (1989) defines implicit learning as an adaptation process through which the behavior of an individual becomes sensitive to a structure [schema] in an incidental manner and without the individual being able to verbally report or even consciously access the resulting knowledge. According to Schacter (1996, p. 172) "implicit memory, by definition, does not involve recollection of source information" and is prone to distortion and error. Implicit memories also play a strong role in motivation and affective responses.

³⁰ For example, see Glossary: *Implicit learning, Hebbian learning, Non-formal learning Informal learning, Tacit knowledge.*

³¹ See Glossary: *Informal learning*

³² It is thought to occur in the episodic buffer of working memory

Implicit processes are considered essential for learning the sequential structure of language (e.g., Cavallin, 2007, Conway et al., 2010). Conway emphasizes the importance of structural consistency for improving sensitivity to sequential structure, a prerequisite for sequence predictability. When attempting to influence schema formation in task-focused applications that reflect sequential processes, it then seems sensible to consider sequence learning along with relationships. Learner age does not appear to be as strong a factor here. Bennett, Howard Jr., & Howard (2007) found that older adults remain sensitive to highly complex sequential regularities in their environment, just to a lesser degree than younger adults.

Cleeremans (1999) points to the issues of consciousness, separate memory systems, and whether properties of learned information differ based on explicit-implicit distinctions as the key areas of contention. There are many reasons that participants may not indicate conscious awareness so this criteria can only be used as an indication, not evidence that learning was implicit. It is, however, a common metric. In all of the domains of research into the dichotomy of implicit and explicit processing, it has also been difficult to behaviorally parse the two because of the process purity problem (e.g., Curran, 2001). That is, both processes occur concurrently in real human learners and experimental tasks involving them. Truly process-pure tasks likely do not exist (e.g., Jacoby, 1991, 1998). Evidence indicates that neurologically these two processes involve distinct activation patterns in different areas of the brain but behaviorally, differences are less distinct.

In this dissertation the explicit-implicit distinction³³ is treated as a continuum between conscious, attentive learning and unconscious, unaware learning with different characteristics exhibited at different stages. Since both can and do operate concurrently, it is only a matter of degree: one chooses which point along the continuum to emphasize. For the purposes of finding guidance for embedding a conceptual model to act as an implicit instructor, there are sufficient commonalities to treat these differing approaches as a unit. The following overview points to these

³³ See Glossary: *Implicit-explicit distinction*.

areas of agreement and clarify assumptions used in this dissertation.

Reber (1993) proposed five characteristics of implicit memory and learning that differ from explicit memory and learning:

- Robustness
- Age independence
- Low variability
- IQ independence
- Commonality of process.

Shanks and St. John (1994) propose these additional criteria:

- Information criterion—the information provided on the awareness test must be the information that is responsible for the improved performance.
- Sensitivity criterion—the test of awareness must be sensitive to all relevant knowledge.

Implicit or incidental learning happens by simple exposure and interaction with environmental stimuli, whether in a physical or digital setting. Implicit learning does not mean that explicit processes are excluded and vice versa - they can operate in tandem. There are three main types of research on implicit learning³⁴:

- Looking at whether healthy participants can learn fairly complex material in the absence of conscious awareness.
- Looking at brain-damaged patients with amnesia to decide whether their implicit learning is intact.
- Using brain imaging to see if different areas are associated with implicit and explicit learning.

Of interest here are first type of study, especially those that look at interactions with different strategies and online environments. Ash & Nokes (2003), for example, used the common serial reaction time (SRT)³⁵ and artificial grammar approach and found that differing instructional methods had no effect on performance, in contrast to

³⁴ See Schacter (1987) for an historical perspective of early research and Schott et al. for more recent activity.

³⁵ Although used extensively in implicit memory and learning research, some question its utility as a useful or valid measure.

results from prior research on explicit learning. Only a minimal amount of attentional focus on relevant stimuli was needed to acquire implicit knowledge from either approach. Cavallin, H. (2007) also used grammar to look at the implicit learning of a set of rules imposed by a finite states grammar. Participants were asked to recognize grammatical items out of a set of grammatical and non-grammatical items, after an exposure to grammatical exemplars. Tunney (2003) used a finite-state grammar to find that priming and recognition decay at different rates for implicit and explicit knowledge.

The SRT tests³⁶ and the artificial grammar learning paradigm reflect a common approach to incidental learning and implicit memory (e.g., Chan, 1992). These methods, together with technical contributions like fMRI, are valuable in teasing out some of the details but it is risky to theorize about the nature of complex cognitive processes as a whole, such as language or implicit learning, "in isolation" (e.g., Reber, 1993). A more ecologically valid approach is reflected in the field of Cognitive Informatics³⁷ which places emphasis on real tasks in their problem-solving contexts (Chan, 2003). Antony & Santhana's (2007) research is an uncommon example of incidental learning in a more authentic and online environment. They use a knowledge-based system (KBS) which is primarily developed to help users in their decision-making activities. Results supported implicit learning through interaction with the information-based program. This is posited to also apply to the type of task- and process-oriented applications used in the current study. This study follows this latter path to look at how incidental learning might operate under more realistic and complex conditions. This can determine whether the specific facets of schemas: relationships, sequence, and vocabulary (necessary symbols of abstract concepts) can be acquired implicitly.

Cognitive Load Theory (CLT)

Since working memory is limited and sets of inputs must be processed together, new or unfamiliar, poorly chunked information can overload mental

³⁶ See Glossary: *Serial Reaction Time (SRT) tasks*

³⁷ See Glossary: *Cognitive informatics*.

capacity. Cognitive load theory offers an explanation of this condition and assumes that information should be structured to reduce working memory load in order to facilitate schema acquisition and meaningful, durable learning. Instructional formats, the nature of tasks³⁸, as well as information quantity and complexity can impose processing loads. Reducing memory load can release cognitive resources to be applied to the learning goal.

The theory has been particularly applied to formal learning, with a focus on guiding instructional design. Sweller, who formulated this theory, treats schemas, or combinations of elements, as the cognitive structures that make up an individual's knowledge base. (Sweller, 1988). Sweller & Chandler (1991a) see all instruction as inherently imposing processing load³⁹. Some of this load is unavoidable as processing attempts to relate new material to prior knowledge. Any opportunity to reduce processing effort must therefore focus on the design of the instructional context, the materials, strategies, settings, etc. In the case of computer-based instruction, the interface must be considered along with the page contents. They recommend part-whole approaches that first present smaller conceptual chunks or "subschemas" with attention to sequencing and relating them. This is consistent with more deductive instructional methods.

Sweller 's theory proposes that instruction material be designed along these principles:

- Use goal-free problems or worked examples in problem solving tasks.
- Present integrated sources of information to eliminate the need for students to split their attention between multiple sources of mutually referring information (also Chandler & Sweller, 1991).
- Reduce redundancy to reduce unnecessary processing.

³⁸ Dreisbach & Haider (2009) discuss information shielding in the context of goal-directed tasks.

³⁹ See Elen & Clark, Eds. (2006). Contributors to the book respond to the statement "learning environments are increasingly complex" to review what is known about complexity and to make specific suggestions for educational practice and for future research.

- Use both auditory and visual information where both are non-redundant to understanding.

Cognitive load depends in part on the level of expertise in a domain as well as familiarity working with different types of materials, including online applications. For example, Kalyuga et al. (1998) found that novices benefit from additional text (e.g., labeling) on diagrams whereas more expert learners have more developed schemas and do better with a diagram only. Conditions of performance also have an effect. Task characteristics impact load differentially, for example, whether steps can be performed sequentially, whether elements interact and must be integrated (considered jointly, processed in parallel) to interpret, the level of segmentation (number of process steps), relational complexity (number of interacting variables), etc.

Paas, Tuovinen, van Merriënboer, & Darabi (2005) identify motivation as a dimension that determines learning success, particularly in online environments. These newer settings can impose substantial cognitive load and effects have not yet been adequately studied to determine how this interacts with current guidelines..

Ang, Zaphiris, & Mahmood (2007) offer a novel perspective, suggesting that cognitive load may be a positive effect of interaction in online environments. They used qualitative methods to explore cognitive overloads in massively multiplayer online role playing games (MMORPGs). These have complicated social dynamics that operate within complex online environments. While some of the anticipated overloads pose serious problems even to expert players, they found that players developed strategies to overcome them. They posit that some forms of cognitive load are actually desirable in order to make the game challenging. These effects may interact with motivation, a factor that may differ between environments viewed as entertainment versus those perceived as work-related.

Cognitive load theory more recently has focused on issues related to

complexity⁴⁰ (van Merriënboer & Sweller, 2005; Sweller, 2006; Mayer, 2006). Interacting with complex systems such as organizations, digital applications, and mechanical devices is an integral part of our lives. Learning them can be a challenge, even when techniques like visualization are applied. Research shows conflicting effects on acquisition under conditions that vary medium, verbal or graphic, and ability/expertise. Those effects are clarified by recognizing that complex systems have structural organizations, parts and their relations, and functional organizations, operations and consequences. For example, diagrams can convey a variety of functions by the addition of arrows. Diagrams are effective for those with high mechanical ability/expertise but difficult specifically for functional information and for those with low ability/expertise.

Information visualization⁴¹ techniques are widely studied and applied to reduce complexity and add meaning. Visual methods of representing people, ideas, and events are as old as humans but its current instantiation stems from human-computer interaction research and information science. In this context it uses spatial and graphical techniques designed to take advantage of human perceptual and cognitive characteristics for the purpose of communication. A visualization should not only provide structured access but also expose relations within content regions while representing the entire phenomena (e.g., Gordin & Pea, 1995). Ramadas (2009), as with others concerned with knowledge discovery, emphasizes the uses of imagery for schema formation and conceptual change. He contends that an principled, evidence-based framework for visio-spatial methods is still lacking in education despite the fact that such approaches are applied broadly, and new methods are continually developed.

Tufte⁴² (1997, p.9) writes "Assessments of change, dynamics, and cause and effect are at the heart of thinking and explanation. To understand is to know *what cause provokes what effect, by what means, at what rate*. How then is such

⁴⁰ Theories about complexity exist in different fields. Chaos theory in math and physics looks at dynamic systems. Organizations study complexity and related strategies from a management perspective. It is applied to Economics and various uses of Systems Theory.

⁴¹ See Glossary: *Information visualization*.

⁴² Tufte is a widely acknowledged visualization expert, a designer/architect and statistician by training.

knowledge to be represented?" Answers to this question in the context of promoting usable schema formation continues to be explored from many perspectives. Tufte's guidance addresses important perceptual characteristics, a prerequisite to comprehension. Tufte recommends that design use the "smallest effective difference", defined perceptually as the "just noticeable difference" - contrast is an important feature, as is muting secondary features like pointers to reduce clutter (p.73-74). Spatial parallelism connects and groups visual elements to help define relationships and sequence. This technique is especially important in the defining the navigation interface when trying to clarify the structure of an application and enhance its informativeness.

Visualizations are intended to expose and clarify, that is, simplify, complex data sets and ideas but can increase cognitive load when unfamiliar. There is little research into the effects of novel interfaces when presented without explanation or training but it is sensible to assume these will be subject to the same preference for familiarity. Zajonc's (1968) "mere exposure" effect says that repeated exposure to a stimulus will improve attitudes toward that stimulus. Novel visualizations such as used in experimental navigation interfaces may take time to adjust to - how much will depend on factors not yet studied in detail. The results of Hansen & Wänke's study (2010) suggest that the effect of exposure on attitude or willingness to accept novelty is an implicit learning function that is independent of conscious recognition. Straub (2004) also reports that exposure time has a strong effect on attitudes and suggests that efficiency of task completion may not always be a reasonable measure in all situations.

Visualization techniques will usually help under conditions of complexity. Multiple methods have been tried⁴³, many are in use to illustrate informationally dense concepts such as found in the sciences, yet few have been used to manage the interface, and fewer still in complex applications. The navigation interface, if it is

⁴³ Hierarchical data techniques include fish-eye views, tree maps, beam and cone trees. Hypervariate data is often represented by types of scatter, star, and parallel coordinate plots. Distortion and animation techniques can be applied to timelines and event streams, zoom & pan to landscapes, and semantic zoom to whole-part object displays.

to move beyond a simple listing of contents, can benefit from the large body of research in visual cognition and its application to user interface design. It must be noted here, however, that the visual interface is not synonymous with a graphical user interface (GUI)⁴⁴. The GUI represents an evolution from typing commands to selecting objects (still usually text); it is primarily an interaction method⁴⁵.

Navigation

Navigation is the purposeful movement through space. The sense of space and our position in it is a fundamental part of our existence. Interactions with the physical environment shape how we think. It is no surprise that navigation has been well-studied in such different fields as architectural design, urban studies & spatioLOGY, geography, sociology, information science, robotics, semiotics, linguistics, narrative approaches & other social forms of navigation. In psychology the focus has been primarily on spatial learning⁴⁶, the use of configural knowledge (environmental layout), and resolution of visual detail.

Research about navigation is widely accepted as applying to both physical and electronic environments. Jul (2004) identifies a four-part, interdependent cognitive task model of navigation:

- locomotion (movement between distinct locations),
- wayfinding (decision making about path),
- spatial knowledge preservation (storing retrievable knowledge about places), and
- information-gathering (the collection of information about the environment).

The physical world naturally provides ways to make navigation easier and more predictable. These include visible, prominent environmental features, color cueing (green grass versus blue water), relative position of the sun and star clusters,

⁴⁴ See Glossary: *User Interface (UI)*

⁴⁵ For example, Lane & Napier (2005) stated that even experienced users are inefficient in their use of graphical interfaces. The study looked at the use of keyboard shortcuts versus pull-down menus and icon toolbars.

⁴⁶ Spatial abilities required by navigation are believed to reside primarily in the hippocampus (Redish, 1999).

and landscape variation. Humans add signage, roads, and landmarks. In electronic worlds cues can include text and text labels; icons, symbols, and images; and perceptual details such as color, shape, and form, relative location (grouping) and visual density. In virtual environments examples include view-in-view maps, animation guides, and human system collaboration. On the web, breadcrumbs⁴⁷ are a common orientation method.

Thorndyke & Stasz (1980) describe three stages in the process of becoming familiar with a new environment. Spatial orientation occurs first based on salient features, landmarks, in the environment. Route knowledge, the ability to move from place to place, then develops using visual cues to make decisions. Configural learning is the third and final stage where the frame of reference is shifted from ego-centered (landmark and route) to a world-centered frame of reference. This knowledge of the structure of the environmental is represented cognitively in a form which Tolman in 1948 called 'cognitive maps'.

Three frames of reference are used to describe strategies employed during navigation: absolute navigation (coordinate system-based, environment-centered, e.g., lat-long), allocentric navigation (intrinsic, external loci, object-centered), and egocentric navigation (relative and observer-centered). Allocentric navigation is based on the use of distance and direction. It requires construction of a cognitive map. It explains latent learning and shortcut abilities. It is also considered a spatial updating model. Egocentric navigation uses relative position of landmarks. All offer paths to new, more informative methods of navigating online. Kerr (1990) stresses the importance of cueing to the user's ability to form a mental representation of the structure of the space.⁴⁸ Chun & Jiang (1998) submit that visually acquired, meaningful regularities in the environment such as spatial layout or landmarks implicitly sensitive perceptually processing to aid in the formation of an internal map.

Lynch (1960), in the context of architecture, proposes that mental maps consist of five elements: (1) paths: routes along which people move throughout the

⁴⁷ See Glossary: *Breadcrumbs* for an overview of research in this area.

⁴⁸ Refer to the discussion about conceptual cueing under the earlier section on Schema formation.

city; (2) edges: boundaries and breaks in continuity; (3) districts: areas characterized by common characteristics; (4) nodes: strategic focus points for orientation like squares and junctions; and (5) landmarks: external points of orientation, usually an easily identifiable physical object in the urban landscape. Of these five elements, paths are especially important according Lynch, since these organize urban mobility.

Park & Kim (2000) examined aids in the form of two types of contextual information, structural (supports forward navigation) and temporal (supports awareness of path taken, backward navigation). Breadcrumbs were developed to serve this latter, temporal function but are not consistently available. Schematic maps are also considered a type of wayfinding aid (Freksa, 1999). In this study this approach, combined with that of concept mapping, has been used to develop one of the navigation interface variants, MAP.

In an early study that looked at the interaction of information visualization and navigation Chimera (1992) proposed that interfaces needed to support these features (still considered relevant after years of technological change):

- the ability to see in one view an attribute distribution,
- provide an overview of “important” items (as defined by attribute values) in a visualization like the fisheye view,
- accommodate/consider available real estate: screen space footprint,
- allow the viewer to see at once many attribute overviews,
- help the user locate outliers and exceptions, and
- offer extremely low cognitive load navigation.

Without such aids, disorientation can add to cognitive load and affect willingness to continue use of an application. Often spoken of as the ‘lost in hyperspace’ problem, in navigation studies this refers to a degradation in performance due to a lack of a clear understanding of system relationships, its structure, rather than the user’s subjective feelings of lostness. Park & Kim (2000) state that disorientation is a pressing problem in more unstructured spaces such as the Web. It occurs when users fail to realize the temporal-spatial context of their position in the space. The need to preserve this contextual information while

navigating adds to the cognitive overhead. Structural context allows a person to decide destination options while maintaining orientation.

Dieberger & Tromp (1993) addressed disorientation by using a visualization of the content as houses presented textually in a MUD. This literal transplantation of the physical to the electronic world has since become standard practice in online games but remains an anomaly in workplace application where it can be viewed as frivolous. An early exception was an aircraft maintenance and troubleshooting simulation (Swanson, 1995) that used no traditional, text-based menus at all. Where more visual menus are used, even now, they are typically supplemented or duplicated by traditional text lists.

Disorientation is typically measured by revisitation metrics⁴⁹. This is more applicable in information searches such as Google and online stores but is still a less reliable method. Individual curiosity and task focus affect the number of less relevant or irrelevant locations visited in open environments (those where choice are not constrained). In an experiment to look at the interaction of lostness and finding target information Gwizdka & Spence (2007) found that success in both tasks and subjective senses of lostness was best predicted by the similarity to the optimal or expert path and time on task rather than revisitation metrics alone.

The Microsoft Inductive User Interface (IUI) (Windows User Interface Group, 2001) is an example of what happens when design is not informed broadly or deeply enough by interdisciplinary research. In Money 2000 and similar task-oriented applications designers attempted to reduce cognitive load and improve orientation by placing a single task per page in a constrained sequence. While meeting the goal of "easy to explain and understand", disorientation was increased since there was no indication of where one was in the process. There were no cues to suggest the overall landscape of the application that might support an improved schema of either the application or the target domain (financial planning). If the sequence was violated,

⁴⁹ A navigation style reflecting the number of times a person returns to the same web page repeatedly during an information search. See Glossary: *Revisitation*. This is associated with "laborious" or intensive which can indicate weak spatial ability and low search expertise. It can also reflect trial-and-error navigation which does not relate to disorientation and does not necessarily reduce performance. It may be a strategy to compensate weak spatial ability (Juvina & van Oostendorp, 2006).

it was difficult to recover. Such small steps slow the performance of more expert users. In the IUI testing, a partial, more constrained version of the application was created because it was felt that the full application was too large and complex. Results may have not been the same in the more realistic environment. A similar task analysis database in use at Boeing used this approach with similar results and a high error rate.

Interest in more visual approaches to menu design – suggested by a move to the more current term, navigation – is strong yet textual approaches still dominate heavily. These may be due to more practical issues: text is simpler to work with, requires less expertise, and is much cheaper to develop and evaluate. Mackinlay & Shneiderman (1999) list a number of techniques that can be applied to enhance visual approaches to the navigation interface: direct manipulation, multiple views, lens and distortion, focus+context, and data flow. Freksa (1999) discusses appropriate levels of abstractions for map representations.

Discussions of online navigation often use a map metaphor to describe geographic orientation and cyber-movement, semantic linkages (e.g., concept maps) but outside gaming environments, the actual use of a map-like representation for domain navigation is a rare occurrence in interface menu design. Cikir (2008) suggests one reason is that sites lack an underlying geography or structure, conceived as “as unstructured (or at most hierarchical) addresses.” It may also be due to more practical issues: text is simpler to work with, requires less expertise, and is much cheaper to develop and evaluate.

McDonald's (1998) findings for the effect of prior knowledge on navigational approach showed that a map condition was superior to that of the contents list and while expertise mattered in other interface types, there was no difference in the map condition. Swanson (1995) found that although user's preferred a map-like interface when discussing task requirements (because it more clearly reflected process and task options), they consistently used more familiar text-based menus for actual navigation. While less expert users used navigational aids more, it was primarily during browsing rather than goal-directed tasks. A current interest in navigation

design is personalization (e.g., McGrenere, 2007) and automatic adaptation, with Microsoft's 'contextual' menu as a less successful example (item position changes based on use frequency).

Eliciting and Evaluating Conceptual Models

There are numerous approaches used to investigate whether and how different design approaches affect learning and navigation in terms of the conceptual model formed. Using concept maps has become a popular method both as an instructional strategy and as an assessment method. A concept map is a two-dimensional, visually-based, node-link-node representation of the knowledge about concepts and their relationships within a domain. The term conceptual or cognitive map is more typically used when referencing memory structure; knowledge map, mind mapping, thinking process maps, Cmap, and topic map also occur. Cf. also Tversky's (1993) cognitive collage.

Originally used in explicit instructional settings⁵⁰, concept maps have been used to illustrate concept relationships under discussion in classrooms, as scaffolding structures, as knowledge tests, and even to teach domain concepts to Betty's Brain, a software agent (Davis et al, 2003). Concept maps now are also used broadly in business as communication and diagramming tools in brainstorming, ideation, and collaboration. In some cases the term is used for common visual tools like flowcharts and Gantt charting (e.g., SimTech's MindMapper). The many commercial software products can be found under proprietary names like 3D Topicscape, Personal Brain, Buzan's iMindMap, and Mindjet MindManager.

Novak developed the idea in the early 1970s based on Ausubel's (1968) theory of learning development and an explicit constructivist epistemology. It became apparent to him that "meaningful learning was the most important factor in building powerful knowledge structures, and that these could be captured by concept maps." (Novak & Cañas, 2006, p.7). Leake (2004) points out that the Cmap doesn't just reflect internal knowledge, its structure also affects concept importance judgments.

⁵⁰ See Novak & Cañas, 2006 for an historical perspective.

Tergan & Keller (2005) have extended common Cmap features to exploit its visualization capabilities but admit that it can pose high cognitive demands on the user.

Concept mapping typically requires training. For example, McClure, Sonak, & Suen (1999) provided 90 minutes of training in concept mapping techniques before students were given a list of terms and asked to produce a concept map. Without instruction, there will be much variation in level of detail (Swanson, 1995). Some will successfully group, label, and link concepts, others will have large, undefined lists of the same list of words. People's ability to identify relevant concepts varies equally broadly and affects the number of concepts included in a map. These issues have been addressed by scaffolding, used in many implicit studies because it requires only recognition rather than recall (e.g., Zittle, 2004). Techniques include modeling by presenting a partially filled-in concept map to complete, for example, Fill-in-the-Structure (FITS) or 'construct-on-scaffold' (Chang, Sung, & Chen, 2001); select-and-fill-in (SAFI) Schau et al. (2001). One can also provide a list of concepts and also relationships (link terms) that can then be arranged. Halford & Busby (2007) also use a partial completion paradigm in their investigations. These approaches are also described as a continuum between constrained (restricted to a supplied list) and open-ended tasks. In a study comparing the effectiveness of the 'construct-by-self', 'construct-on-scaffold', and 'construct by paper-and-pencil' concept mapping Chang, Sung, & Chen (2001) showed that the 'construct-on-scaffold' had better effect for learning on biology.

Concept mapping is believed to reflect the content and organization of internal schemas but assessment of the accuracy of the produced models is dependent on methods used, the people making them, those assessing them, and the assessment methods used Stoddart et al. (2000). Ruiz-Primo & Shavelson (1996) conclude that: (a) an integrative working cognitive theory is needed to limit the current variation in concept-mapping techniques for assessment purposes; (b) before concept maps are used for assessment and before map scores are reported to teachers, students, the public, and policy makers, research needs to provide reliability and validity

information on the effect of different mapping techniques; and (c) research on students' facility in using concept maps, on training techniques, and on the effect on teaching is needed if concept map assessments are to be used in classrooms and in large-scale accountability systems.

Research generally supports the validity of using concept maps as a mental model elicitation method. The approaches to scoring concept maps typically combine an interest in the content validity or accuracy of the content displayed in the map with an interest in the elaborateness of the map as measured by counting various map components, such as concepts or links. Stoddart et al. (2000). Scoring approaches initially emphasized elaborateness, the number of elements included. The trend now is to compare a learner's map to an expert map for alignment of content and accuracy and may still include measures of elaborateness or richness.

These methods correlate well with more conventional tests, especially multiple-choice tests (e.g., Kealy, 2001; Liu & Hinchey, 1996; West et al., 2000). When comparing test results from a multiple choice test and concept map, Stevens (1998) found reliability for the multiple-choice test was moderate; reliability for the concept map measure was high. There was a positive, moderate correlation between concept map posttest scores and multiple-choice posttest scores. McClure, Sonak, & Suen (1999) found that correlations of map scores with a measure of the concept maps' similarity to a master map provided evidence supporting the validity of five of the six scoring methods investigated. Michael (1995) found the correlation between concept map scores and achievement test scores was "fairly strong".

The navigation interface can be construed as a type of concept map when explicitly designed with a conceptual model in mind. Like a concept map, it organizes related concepts. Main topics can indicate the type of relationship, ordering indicates task sequence, terminology reflects relevant concepts. Model-based interface design,⁵¹ an approach that attempts to map abstract task models into a concrete interface, together with findings from memory, learning, and navigation domains can

⁵¹ See Glossary: *Model-based interface design*. According to Puerta (1998) it is one of the least understood parts of model-based technology.

help identify design options. The correlation with multiple choice tests suggests that these can reveal structural knowledge represented by a concept map approach to the design. Combining the focus of mapping assessments with the more familiar and easy-to-use multiple-choice format may be a valid method for determining the content of mental representations before and after interventions.

Chapter 3

METHOD

Studies of the acquisition of knowledge, both informal and formal, are common. Studies investigating applied learning where tangible products are created in a complex, task-oriented online environment are uncommon. Conducting the study completely online without the physical presence of an investigative team or other type of moderator is rare. This section is more detailed to provide insight into such a process for future attempts at similar online experimentation.

The study was programmed to be conducted entirely online at locations and times chosen by participants using their own computers. The UW Human Subjects Division approved this project on 28 Sep 2010. The study investigated whether deeper structural knowledge, that is, understanding of relationships and sequence of a conceptual model, could be learned incidentally as a by-product of using an application which intentionally embeds such a model. Incidental learning requires simple exposure while performing tasks common to that domain rather than explicit training or help system instruction.

For this study, tasks within the instructional design portion of a complex training system application were performed. Participants were told that they were to take the role of a new hire replacing someone who had been designing several lessons on aircraft maintenance. They were to find required data to see how much work had been finished. They would not edit or create new information during the study, they would only click on target data to indicate they had found each of 20 items.

Participants

Given the limited contact time of participants with the treatments and the expectation of incomplete participation, as large a number of participants as possible was required. Because prior studies did not strongly identify potentially significant interacting traits in this context, this exploratory study targeted as broad a population

as possible. Primary contact with potential participants was made through email. A database of contacts throughout the world was created from friends, relatives, professional contacts, university residence hall advisors, department chairs, and many of the researchers referenced in this dissertation. All were encouraged to forward the email to other interested persons. Several retirement communities included a notice about the study in their newsletters, and posters were hung in university common areas and department bulletin boards from Seattle to North Norway. A Facebook page was created along with a video overview of the study process posted on YouTube. Notices encouraged people to watch the video first and advised potential participants that the study should be approached as a challenging game that would take about two hours. There was no compensation offered other than the satisfaction of helping to complete a dissertation experiment.

The study was available to all persons age 18 or older with no other constraints. The assumption that all participants would have access to a computer and have a sufficient level of computing confidence to attempt the study was self-selecting and appropriate to the type of workplace environment targeted. I recruited participants through educational institutions, workplaces, and social venues using about 1000 individual emails, Facebook announcements, a YouTube video, posters, and similar methods. I encouraged Interested persons to forward the request for participation to their own contacts. Participants were given an email address to contact me if there were problems, some had my phone number, but otherwise were dependent on embedded materials for help. No compensation for participation was offered.

There were 320 accesses to the Study as defined by signing the Consent Form. Data were collected over about a two and a half month period. These were not all unique visitors. People may have had to download Silverlight first or been unable to connect to the database initially, requiring re-access to the Study. Some may have lost their web connection or moved to another computer.

A background questionnaire provided statistical population characteristics. Table 1 shows the distribution of ages by sex. 180 persons completed this

questionnaire. Sixty-five participants completed the study. The missing gender data was due to a temporary programming error.

Table 1. Sex and Age of Persons Starting the Study.

	<i>18- 25 yrs</i>	<i>26-40 yrs</i>	<i>41-55 yrs</i>	<i>56-65 yrs</i>	<i>66 + yrs</i>	<i>Total</i>
Female	26	15	16	18	5	80
Male	16	10	13	12	15	66
Unknown	24	6	0	4	0	34
Total by Age	66	31	29	34	20	

The mean educational level of the initial 180 participants was slightly less than a Bachelor’s degree, 3.8, where 3 is a post-high school technical degree.

Table 2. Initial Participant Distribution by Education Level.

	<i>High school or less</i>	<i>AA</i>	<i>Technical</i>	<i>B.A.</i>	<i>Master’s</i>	<i>Prof: e.g., MD, JD, DDS</i>	<i>Doctorate</i>
Number	43	11	2	57	32	8	22

Time stamps indicated general geographic location based on local differences from UTC. Data was collected following completion of the test for 140 people.

Table 3. Participant Location based on Universal Standard Time.

	<i>PST UTC -8</i>	<i>MST UTC -7</i>	<i>CST UTC -6</i>	<i>EST UTC -5</i>	<i>UK UTC 0</i>	<i>Europe UTC +1</i>	<i>Other UTC +2</i>
Nr of People	85	12	16	12	1	13	1

Based on Questionnaire responses, an instructional experience score was calculated for each participant to assign them to one of two groups. Of this initial group 41 were assigned to the higher instructional experience group (EXP+) and 139 to the lower instructional experience group (EXP-). Within each group, the program then randomly assigned participants to one of three treatments using a 3x3 Latin square sequence: A, B, C, B, C, A, C, A, B.

Design

The experiment is designed to provide quantitative data to look for significant

interactions and trends worth pursuing in future investigations. The qualitative data assist interpretation of that analysis. Because of the lack of direct, experimental precedents, the data are designed to support additional post-hoc analyses if the initial results are ambiguous.

The experimental design is a multivariate, between groups, two-way factorial design with fixed effects. One independent variable is interface treatment with three levels of navigation interface type. The second independent variable is instructional experience with 2 levels, EXP- & EXP+. Fifteen of the 65 participants that completed the study were considered more experienced. Given the exploratory nature of the study, additional population data were collected to use as potential covariates if it was determined that group characteristics did not differ significantly. The only other characteristic that appeared to have some influence in the study was analytical experience. That score was based on related job experience. Twenty-seven of the 65 participants that completed the study had a job that required at least some analytical skill.

Questions investigated the interaction of three dependent measures with the conceptual model designed into the application: Relationship alignment (REL), Sequence alignment (SEQ), and Vocabulary alignment (VOC). Each Knowledge test response was coded: 0 for *unrelated*, 3 for *related*, 10 for an *aligned* answer based on a measure of distance from the embedded model. See Figure 10. The responses for all questions within each dependent group were summed to provide the alignment scores for each participant. Scores for these measure constitute the raw data used in pre- and post-test comparisons.

Scores are interpreted with the support of performance data. These data include task duration and number of task timeouts (duration exceeding five minutes), number of pages visited, number of tasks completed, and a comparison of the first set of 10 tasks with the second, final set of 10. Navigation efficiency is defined as a comparison of participants' navigation paths to a random walk through the tasks and to an expert/optimum navigation path. The navigation efficiency measure was discarded due to the need for more explicit navigation instructions than anticipated.

Insufficient participation and subsequent attrition made it impractical to maintain balanced groups for between-group analyses. No participant data were discarded.

The next section describes the operationalization of variables and types of measures. Details of the database and WorkSpaces application with its three interface designs are found under the *Software* section. Details of the background questionnaire, pre- and post-tests, online task instructions, additional aids, and the usability survey are under the *Materials* section. Experimental tasks are described under *Procedures*, with full instructions shown in Appendix F.

Instructional Experience

The presence or absence of prior categorical or conceptual knowledge is known to affect the saliency of treatment dimensions (e.g., Vandierendonck & Rosseel, 2001) and is expected to apply in both explicit and implicit learning. Since the embedded instructional development model in the software is intentionally specific, it may well conflict with that held by persons with educational or training experience who are presumed to have a more developed schema of related processes. They may also have an affective reaction to the high level of analysis and systematicity of the ISD approach as embedded in ISD WorkSpaces if their work experience did not require such an approach. Such conflicts were expected to be revealed by the dependent measures, user comments, and the brief usability survey.

Instructional experience for this study is operationalized as a score derived from responses to seven Questionnaire answers using a weighted formula rating the participant's own educational level, type of education-related profession, and self-reported level of expertise. Appendix D lists the questions and values given for each response. Scores ranged from 0 to a maximum of 60. Persons with scores less than 15 were assigned to a lower Experience group (initially 71% of participants), those with scores 15 and above to a higher Experience group (initially 29% of participants). The number of assignments to each treatment by the end of the study varied due to a 64% attrition rate. Table 4 shows final group numbers for the 65 completed studies.

Table 4. Treatment Assignments (Completed Studies)

	<i>Treatment 1 Windows Menu</i>	<i>Treatment 2 Web Menu</i>	<i>Treatment 3 Map Menu</i>
Lower Experience	14	17	18
Higher Experience	4	8	4

Analytical Experience

This post-hoc variable provides a general indication of whether a participant is likely to be more or less skilled at performing in a more technically complex environment where closer attention to details and analytical approaches to problem-solving are more common. This score was based on self-reported job experience and was calculated for experience in five job categories. One point was given for an Education Level greater than a Master's Degree (e.g., MD, JD, PhD). Engineering, Systems Design or Development, or Analyst positions (e.g., where one analyzes usability, financial data, cost-benefits, or manages records) with experience of at least one year received one point for each, for a total maximum of 5 points. While the design of the WorkSpaces application accommodated users with a less predictable skill set, it is possible that a tendency toward more analytical processing influenced outcomes.

Structural Alignment Criteria

Alignment is defined here as a positive, neutral, or negative movement towards a match to the conceptual model embedded in the application. Movement toward alignment with the designed conceptual model is analyzed in terms of two aspects of conceptual structure: relationship (REL) and sequence (SEQ). The pretest is used to determine to what extent participants' response is already aligned with application use. Test responses for each of these dependent measures is given a score of 10 when aligned, three when related, and zero if unrelated.

Relationships show group membership and conceptual distance (how similar or different). Procedural sequence reinforces the perception of relationship and adds an indication of prerequisites and a normal flow of events. Structure and sequence

are basic components of analogical processing, are a feature of schemas or conceptual models, and appear to coincide with and influence perceptual processing. Measuring positive change in the participant's mental model of the embedded courseware development process is an indicator of learning without explicit instruction.

Vocabulary Alignment Criteria

Answers from the knowledge tests also provide scores for this criteria. As with structural criteria, responses with terminology matching the application use is scored as *aligned*, semantically equivalent terms are *related*, and non-equivalent terms, *unrelated*. This criteria is used to measure how much application use alone can influence a user's understanding of potentially new terminology in the relatively limited exposure time available, despite the substantial cognitive load imposed by the quantity and complexity of new information.

Specific vocabulary terms used on page content are targeted in the Knowledge tests. For example, the term "Effectivity", common to the business where the application was developed, is applied in a manner not found in common use or any dictionary. "Skill" and "activity" have a more specific use in the application compared to common use and are used inconsistently in the Windows treatment to accentuate differences between treatments. Similarly, the menu item "Shared Data" differs between treatments.

Performance Data

Performance data were collected to help interpret alignment data but, unlike most usability tests, it is not used to assess which treatment is fastest and most error-free. (A desktop version of this application had been in active use with ongoing usability evaluation for nearly a decade.) Performance is not a sufficient predictor of learnability but can offer indicators. Because there are few direct precedents for this experiment, it was not known which type of performance data would be most informative so data collection was designed to accommodate a variety of measures. Those finally used in the analysis were relative task difficulty, number of tasks

completed, task set times, and number of timeouts (where time on task exceeds five minutes). Overall mean duration scores per task give an indication of task difficulty.

Time Data

Contact time with the application is required, not successful task completion. Time data allows consistent comparisons and assists interpretation of other data. Time provides a general indicator of difficulty, verifies performance sequence, and identifies tasks associated with User Comments. The raw time data is a time stamp on the mouse event for each tracked click: page access and control buttons, as well as times for automatic events such as signing the consent form and timeouts. Task times are measured from task start (clicking the “CLOSE Notebook” button on the Instructions page) to the time stamp for closing the “You Found It” message or a click on the Skip Task button. Both these actions log the task end time, automatically increment the task, and open the Notebook with instructions for the next task.

A timeout function, Skip Task, was added after field trials indicated that it was likely that participants would not explore more but instead quit the study if they were unable to complete a task quickly. The timeout function automatically displays a message after five minutes to allow participants to skip a task if they have not been successful in locating target data. The participant is given the choice of continuing to try, to look at step-by-step instructions, or to move to the next task. The message generates a time stamped comment in the data log and also records whether or not a participant waited for the task to timeout rather than continuing to look for the target (NoNav Timeouts).

Times logged are dependent on the speed of the Internet connection, the computer, and what other database updates are already queued. In such online experiments they cannot be construed as precise. For an exploratory study such as this one, time precision is not critical.

Task Difficulty

Relative task difficulty is assessed by the number of clicks required to complete the task, whether the task was performed in the normal sequence as

reflected in the underlying process, and mean time-on-task. This does not necessarily correlate with participants' perception of task difficulty.

Navigation Data

Field tests showed that few participants would be able to complete tasks without more help than was planned. The navigation part of task instructions was made more explicit, greatly reducing likely route deviations. A planned comparison of the navigation path scores (number of clicks or pages visited) between an expert path and participants was abandoned. Time spent per task, however, remains a useful metric, especially comparing the first half of tasks with performance on the second task set.

Task Set Data

The first set of 10 tasks is sequenced following the designed development process. The WEB and MAP navigation menus reflect this order. Access to the task target data is always on the primary page. The second set of 10 tasks was randomly ordered, required more clicks to access the target data, and in three cases, required navigation to a sub-page.

Subjective Usability

The Usability survey and comments submitted collect subjective assessments of the difficulty of the tasks and operation of the interface, importance of visibility and aiding features such as color and labeling, and preference for image vs. text. These preferences can be used as qualitative inputs to interpret the quantitative data.

Software Description

The software application which provides the environment for the experimental tasks is a learning content creation and management tool (LCMS) originally developed by the investigator for use by the US Air Force and The Boeing Company from 1995. It was originally built on top of an MS Access database for use in a networked desktop environment. A web implementation of this tool, ISD WorkSpaces[®], was developed for this study and integrated with new software to

present and manage all aspects of the study. This package allows all experimental materials to be available at a single site online and all data to be collected into a single package in a separate, secure SQL database.

Page content is the same for all three treatments with the WIN menu showing intentional vocabulary inconsistencies. General instructions point out page areas used to select hierarchical data, to contextually search large data sets, and to view the resulting data where task targets can be found. About 90% the data from one of the aircraft sets has been removed to improve processing time and reduce user confusion. Similarly, only those pages referenced by the pre- and post-tests are active. All other pages are retained for context; they show an image relevant to page content when accessed (see Appendix K). Only command buttons required to select data are active. Most buttons for editing functions such as delete are inactive with a tool tip reminder.

The MS Access database was converted to SQL Server for a more robust implementation and to interact more readily with the web-based WorkSpaces and LINQ queries. Additional tables were added to collect study data as well as manage correspondences between pages, tasks, instructions, and test materials.

The application software was developed using the Microsoft Silverlight framework. Part of the application resides on a server (the host provider is 3Essentials.com), part on the client (the user's PC) as shown in Figure 2. The client

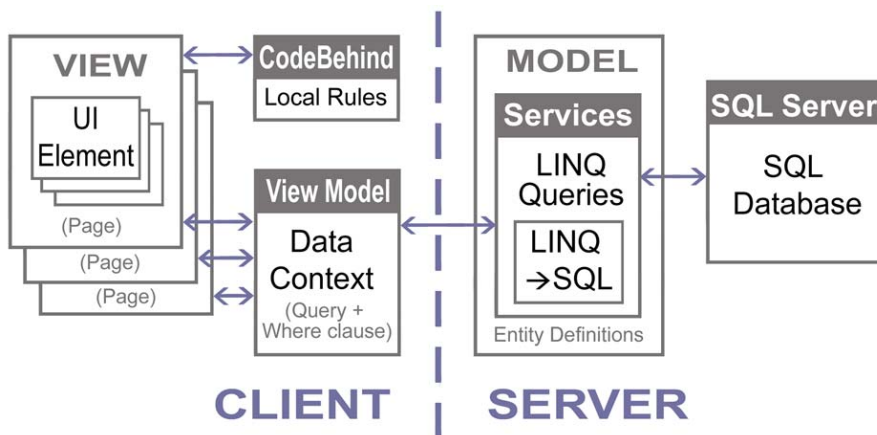


Figure 2. Study client-server architecture

needs to have the Silverlight browser plug-in which allows the application code to control the user interface. A temporary cookie is created so the user can return to the study without starting over if there is a disruption such as loss of internet connection. This cookie has the GuestID and expires after 24 hours. It is not accessible to the investigator or from another computer.

Initial pages use html to open the Silverlight application. Each subsequent web page or view is authored in xaml and presents the user experience. Separate C# code-behind and view model files control that experience. Code-behind manages unique page events and their rules. All other page events reference global view model files. View models maintain user context, manage integrated help functions such as Search tip pages, identify non-active controls, generate queries to populate data, and apply rules to change page appearance. Only view models communicate with server-side services. Silverlight uses LINQ to manage queries and uses a LINQ-to-SQL converter service to communicate with the database.

The Notebook is a separate but integrated application with access to the timeline of the user's workflow and context – the where, when, and task status. For the questionnaires and tests, it is full-screen and controls page sequencing. During the Find-It part of the study, it is accessed through a control button. It then shows study progress, collects user comments, controls task instructions, and provides contextual help. A reminder of the next task target displays on hover over the Notebook control button to reduce the need to repeatedly access the Notebook to review instructions. To encourage participants to leave comments, the Comments and Progress page shows automatically after the completion of each task. This page is accessible at any time during the Find-It phase.

The Study Workflow and Services diagram expands on Figure 2 to show the progression of pages and the services they use. Services are code which runs on the host provider and communicates with code running on the client. Services can directly interact with the SQL Server database to formulate and issue questions with search criteria and return results to the client. Services also create and modify entries to the database for user actions and responses.

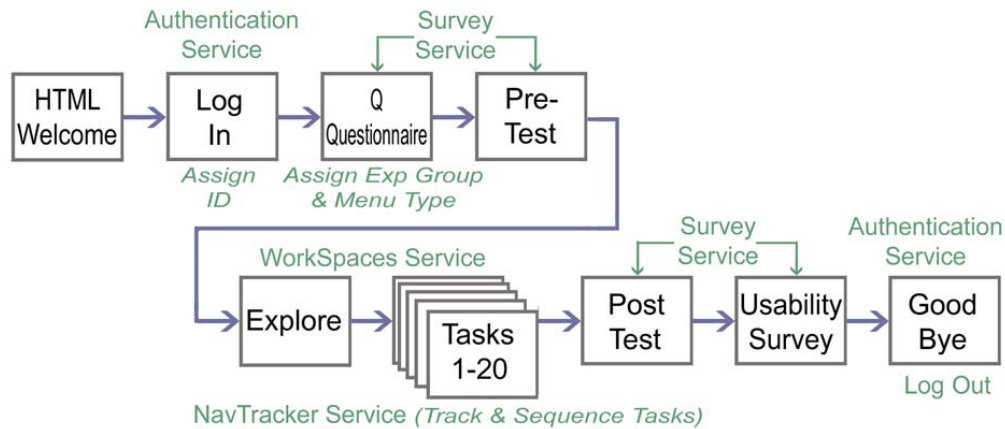


Figure 3. Study Workflow and Services

When the participant clicks to sign the consent form, the Authentication service creates a permanent UserID, initiates the study process, and records a start time for the participant. It updates the ending time for the Study when the final page is accessed.

The Survey service records user answers and start/end times for each questionnaire and test. Based on answers to questions relating to instructional experience, this service calculates a score and assignment to an experience group, then randomly assigns a treatment (menu type), and updates the participant's database record.

The NavTracker functionality, added to the LCMS for an earlier pilot study, was extended to record the time and location of every page access and use of selected controls. The service also keeps track of the Find-It tasks and evaluates when a task target is found. The NavTracker service operates only within the WorkSpaces application and provides the primary performance data.

The Workspace service is a read-only service which provides data to populate forms on the pages. Participants can select data on pages views but any edits are not saved or written to the database.

Navigation Interfaces

The three navigation designs represent the spectrum of existing approaches.

Each treatment varies in how explicitly the menu shows grouping of page locations (REL), prerequisite processes (SEQ), and how consistent menu terms are with their use in page content (VOC). Each menu is located on the part of the page most common for its type. For consistency, all pages have a bar at the top and left side that accommodates navigation interfaces and controls. The Notebook icon is present in all three versions. All menus are visible without scrolling although the map version initially shows only its OPEN button. Many web sites are now using multiple primary menus, using differing categorization methods for each and partially duplicating targets. These sites are usually focused more on information access than task performance. In this study there is only one primary menu location for each treatment.

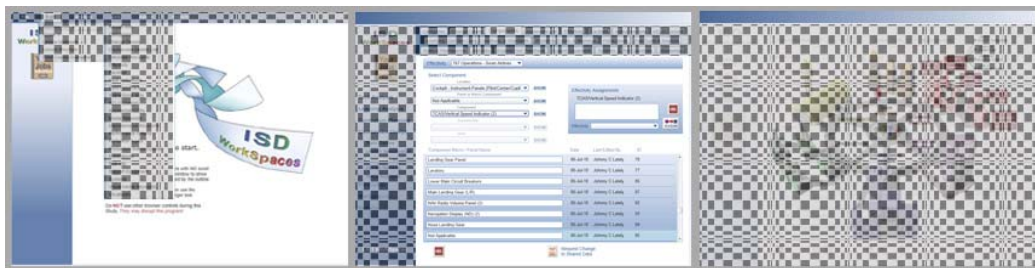


Figure 4. Relative screen coverage by each menu style: WIN, WEB, MAP.

The shaded areas in Figure 4 show the percentage of screen space taken by each type of navigation menu when open. The WIN (left) size is total of each open cascaded menu selection which varies from 6% to 19% based on main menu item. The tabbed area on the WEB version is necessary to access all the Shared Data Resource pages. It is retained on the other menus for consistency. When present, it increases WEB coverage from 17% to 33%. The MAP version uses the full screen.

The pervasive, Windows style, taskbar/pull-down menu (WIN, Figure 5) provides a baseline approach. A 2-level accordion menu common to web-based interfaces presents an intermediate approach that is conceptually comparable to tabbed horizontal menus (WEB, Figure 6). The third style, an innovative graphical map interface (MAP, Figure 8), uses visual characteristics of geographical maps rather than the node-link format of the textual concept or knowledge maps from which it is derived. (See Appendix J for examples of similar menus.)

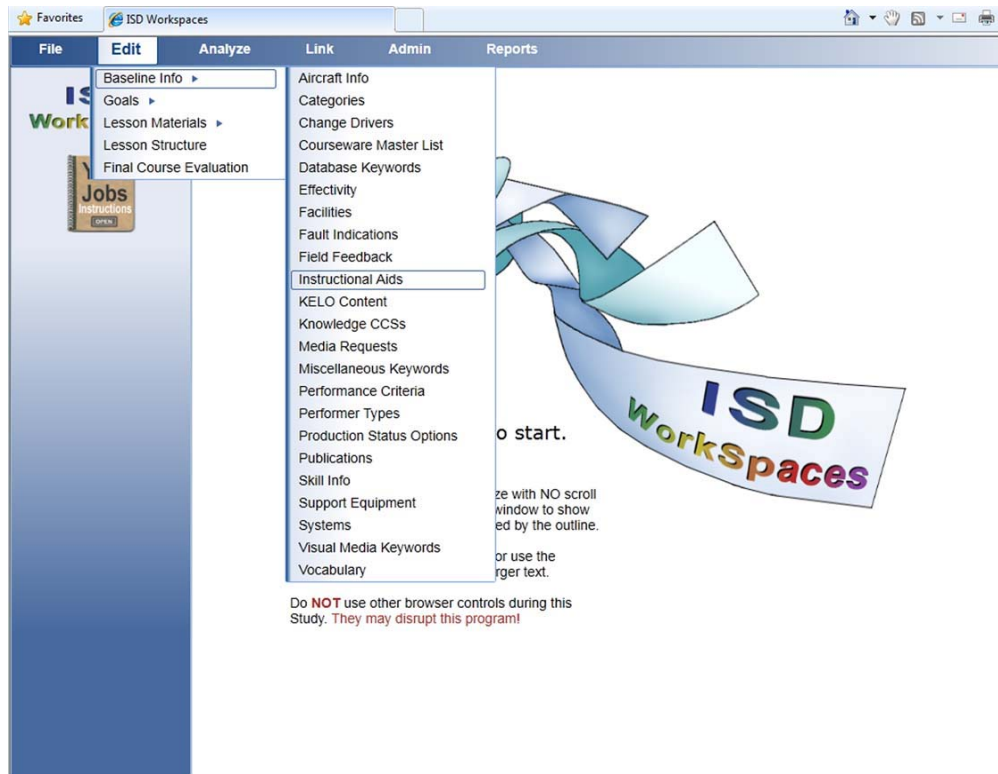


Figure 5. Windows-style pull-down navigation (WIN)

The Windows menu uses a function-based main menu bar that is always visible at the top of each page. Cascading menus use separate list boxes to indicate only hierarchical organization. They typically have multiple levels and are organized by tool functions (file, edit, analyze, reports, etc.) rather than following a task process sequence as do the WEB and MAP. The WIN type of menu also allows for a column of icons illustrating the text item (usually placed to the left of the text labels). Selection of an item highlights the text and shows a submenu list as long as the cursor remains in the target area during the selection process. The version in this study uses text-only labels, no icons. Arrows (carrots) indicate the availability of an additional, third menu level. (Three levels was the maximum used for any of the three navigation interfaces.) Hovering or clicking on an item with a lower menu level opens that window but a click is required to actually go to another page.

Unlike the other two treatments, the WIN menu does not reflect the conceptual model of the tasks the tool is designed to support. This lack of context in WIN style

navigation is proposed to inhibit schema formation. These characteristics and the topic/verb categorization approach are its primary difference from the other navigation modes.

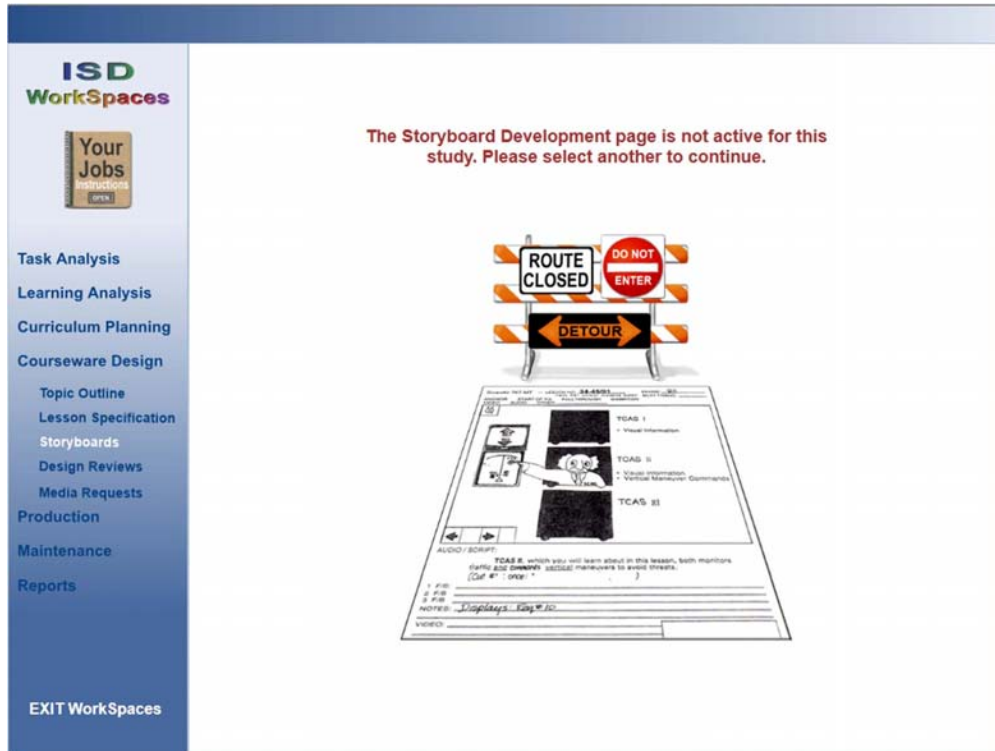


Figure 6. Web-style accordion navigation (WEB)

The WEB menu (Figure 5), like the majority of website menus, is a vertical bar on the left side of the page. Like the WIN menu, it also uses text-only labels but these directly reflect the processes defined by the underlying conceptual model. Initially only the seven main menu items show. When the user hovers over one of these, a submenu shows. If the cursor is moved over another main menu item, the prior submenu closes and the new one opens, accordion-style. The WEB version uses font size and weight, indents, color, and highlighting as perceptual aids. For example, when an item is selected, the new page shows and the indented submenu item is highlighted to show present position. There is only one level of submenu, in contrast to the WIN menu. Only the web version continuously shows a submenu for the active main menu selection.

The Maintenance category has a large volume of data entry pages that cannot

fit an accordion menu like WEB so each set of these pages have a secondary, tabbed submenu as supplementary navigation (Figure 7). Since the content part of pages is the same for all treatments, these tabs are active for all menu versions.

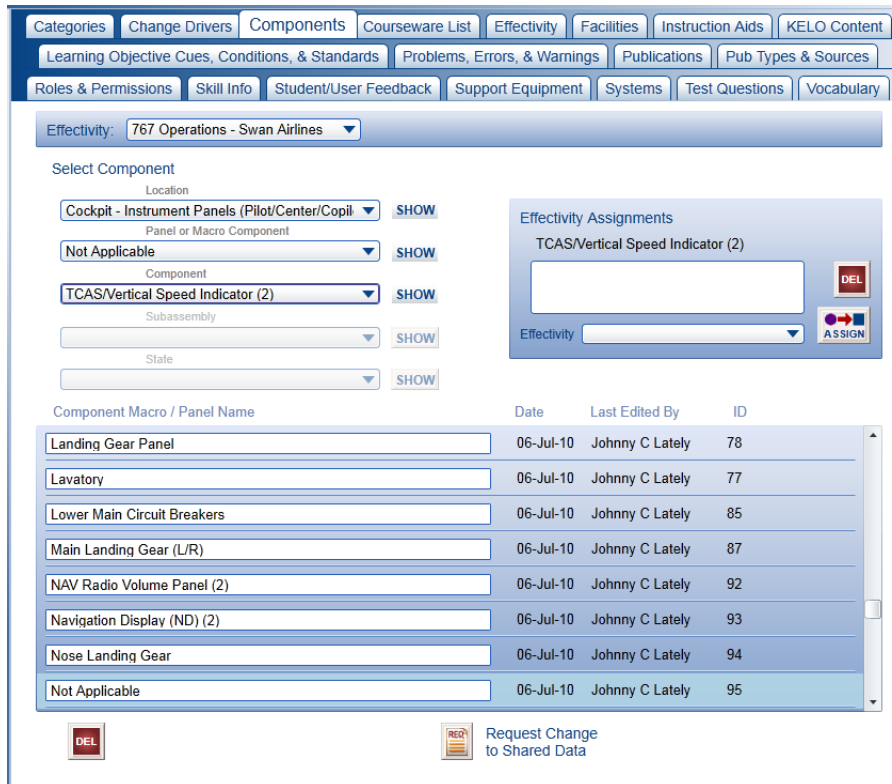


Figure 7. Secondary tabbed menu heads Shared Data pages.

There is little precedent in computer interface design for the MAP menu (Figure 6). It was conceived as a more visual version of a concept map, highlighting conceptual and process relationships and sequences by labeled images. It is opened from a control button on the left plate and then overlays the entire page. The current page remains visible but muted underneath to retain navigation orientation. It is navigated in a clock-wise sequence, reflecting the normal order of the training development and maintenance processes. Additional paths indicate sequence flexibility. (Appendix H shows the Map Key which explains visual elements.) Center buttons control the amount of additional information which can be displayed. The green arrow button closes the Map and displays the prior page.

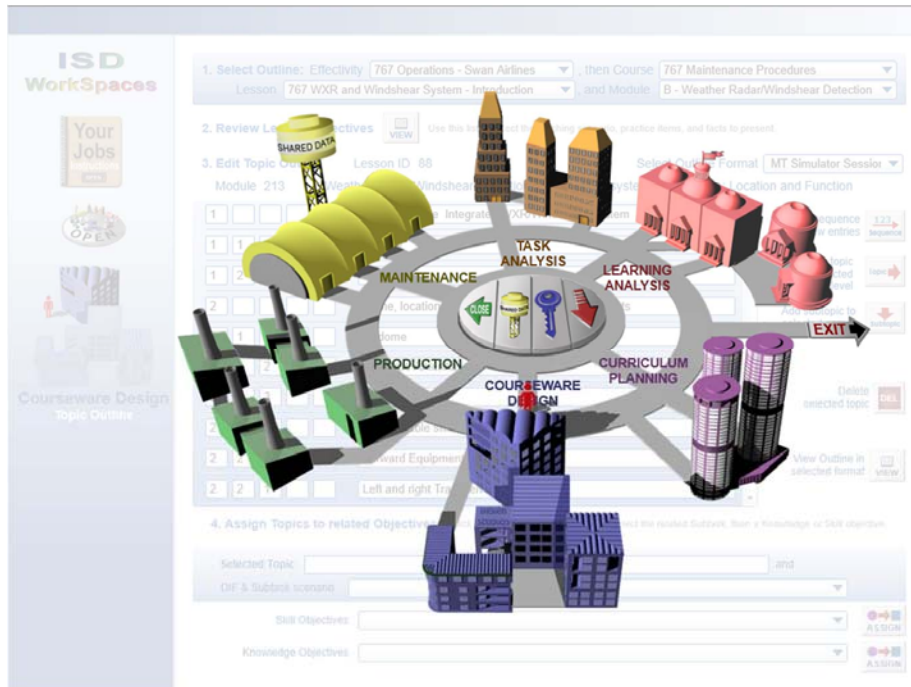


Figure 8. Map-style graphical navigation (MAP)

The MAP version uses perceptual aids and offers conceptual support more extensively than the common navigation approaches reflected in the WIN and WEB versions. Submenus on the MAP version show on hover for one main menu group at a time. When the cursor is positioned over a group, labels show for each page within the group. A background, pie-shaped highlight reinforces which pages are part of that process. When hovering over a specific building or its label, an explanation of page function appears. (Figure 9 and Appendix H show examples.) Page-specific information is available on hover when a toggle button is in the ON position. When depressed, the button with the Water tower icon lists the Shared Resource data which must be available to perform page tasks. The Key button displays the Map Key. The red Prerequisite arrow shows what tasks must be completed before tasks on the selected page can be done. (Figure 9)

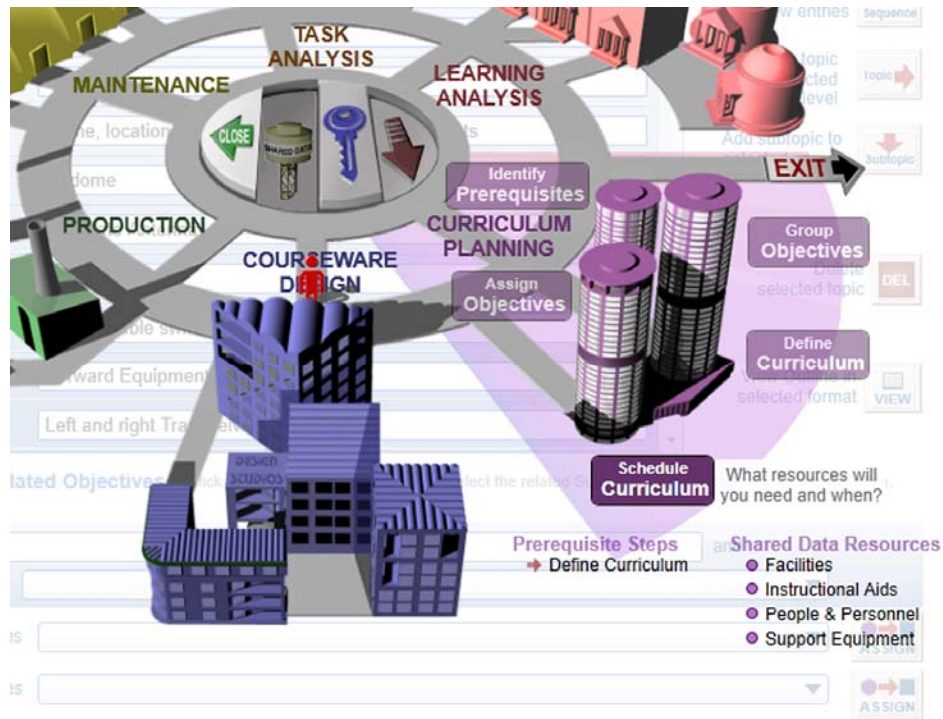


Figure 9. Conceptual support: MAP Navigation.

The lack of a breadcrumb feature has been shown to cause disorientation. In keeping with the traditional design of drop-down menu types, WIN has no location support. The WEB navigation opens the main menu and keeps the selected submenu visible with the current item highlighted. See Figures 4 and 5. The MAP menu uses breadcrumbs both when open and closed. When closed, an image of the task group/main menu shows below the Notebook button. The selected page building is highlighted in context, acting as a breadcrumb. (Navigation to other areas in the group from this breadcrumb was not implemented for this study.) When the MAP is opened, a small figure stands in front of the current location. Figure 10 shows the two uses: on the content page side panel (left image) and on the opened MAP menu (right image).



Figure 10. MAP breadcrumb feature. Content page and open menu.

A challenge with the MAP type is the amount of screen real estate required relative to the other types. It prevents the navigation menu from being visible at all times. This characteristic was found to have a major impact in a previous study (Swanson, 2005) where participants judged a similar map interface more informative but almost exclusively chose to use the fully visible version when both were available. Howard (1982) finds that horizontal and vertical layout have privileged status in the world as well as in perception. The MAP violates that preference but this might be mitigated both by its similarity to familiar geographical maps and by current preferences for visual over textual information in many contexts.

Table 5 indicates the visual-spatial-semantic properties of each interface and the navigational resources available. If one interface produces larger effects, further experimentation can use these criteria to determine its contribution to schema formation or alignment. It presents items related to physical properties of movement, especially the screen scanning requirements placed on the user, and informational supports available. Note that the top level of the WIN and WEB forms is always visible, active, and requires 2 additional selection clicks. The MAP format uses one click to open the navigation screen and one click to select a destination. Screen percentages vary with WIN and WEB depending on which if any submenu is open.

Table 5. Design characteristics of the 3 navigation menus.

Operational Characteristics	WIN	WEB	MAP
Percentage screen space when open (WIN size is total	6-19%	17%-	100%

<i>of each open cascaded menu selection box)</i>		39%	
<i>Nr. of menu locations on screen</i>	1	1	1
<i>Layout of main menu</i>	<i>horizontal</i>	<i>vertical</i>	<i>circular</i>
<i>Nr. of main menu items/submenu items (excl. EXIT)</i>			
<i>Nr. of hierarchical menu levels</i>	3-4	2-3	2
<i>Nr. of clicks from main menu to task form</i>	2	2	2
<i>Informational Characteristics</i>	<i>WIN</i>	<i>WEB</i>	<i>MAP</i>
<i>Main menu visible from form view (page content)?</i>	Yes	Yes	No
<i>Menu items indicate current selection (breadcrumbs)?</i>	No	Yes	Yes
<i>Submenu context visible from form view?</i>	No	Yes	Yes
<i>Task form visible when menu is active?</i>	<i>Partly obscured</i>	Yes	<i>Faded</i>
<i>Only one submenu group displayed at a time?</i>	Yes	Yes	No
<i>Explanatory information available for menu items?</i>	No	No	Yes
<i>Menu structure indicates process sequence?</i>	No	Yes	Yes
<i>Menu structure indicates prerequisite tasks?</i>	No	No	Yes
<i>Menu structure previews task form activities?</i>	No	No	Yes
<i>Level of visual representation of process structure</i>	<i>Low</i>	<i>Medium</i>	<i>High</i>
<i>Uses additional explanatory labeling such as tool tips?</i>	No	Yes	Yes
<i>Selection feedback</i>	Yes	Yes	Yes
<i>Visual cue use: Color-coding, highlights, fading, zoom</i>	<i>None</i>	<i>Few</i>	<i>High</i>

The effects of these characteristics can be expected to be moderated by the type of tasks the application is designed to support and the environment in which it is used. Environments that are primarily informational and where tasks are primarily searching or browsing are beyond the scope of this study.

Embedded ISD Model

The application for this study requires an embedded structural schema with an associated, defined process and vocabulary. It needed to be sufficiently complex to emulate more modern workplace applications. While any model or application reflecting these characteristics could be used, the source code for an appropriate application was available and allowed for more ready translation to a web-based

study environment. The interface design of this application, ISD WorkSpaces[®], explicitly reflects the author's refinement of a systems approach to instructional systems development with the addition of templates designed to embed instructional expertise and support data re-use. The model was drawn from a number of military specifications (as examples, see US Dept. of Defense, 1999; Knirk & Gustafson, 1986). ADDIE is an early example. Models such as van Merriënboer and Kirschner's (2007) 4C/ID model are conceptually similar but focus primarily on task and learning analysis processes.

The WorkSpaces model separates Task Analysis (jobs people do) from Learning Analysis (how to teach these jobs) rather than combining such distinct goals into one Analysis category as is common. The implementation stage has been renamed Maintenance to reflect not just the launch of courseware and summative evaluation but also long-term management and revision activities. The embedded model has been validated by numerous academic, military, and corporate instructional experts repeatedly during its design and implementation. It has the characteristics of complexity, task-orientation, and process-based applications which are increasingly found in large enterprises and therefore meets the contextual requirements of this study.

The following diagram expresses the instructional model embedded in the application. The primary characteristics of this ISD model are a systems input/output model, iteration, and progressive evaluation. The outputs of each process stage are the inputs necessary for the subsequent stage. The process is not inherently linear although under ideal conditions it is most efficient to develop courseware in this sequence. Existing curricula, partial data, changes due to review, new knowledge, etc. all are part of everyday conditions in a training venue and require iterative and flexible access to all stages at any time. At the data level, prerequisite data will need to be produced before implementation of a course to permit full capability of the system to track, integrate, and otherwise maintain the courseware but such measures are encouraged rather than enforced.

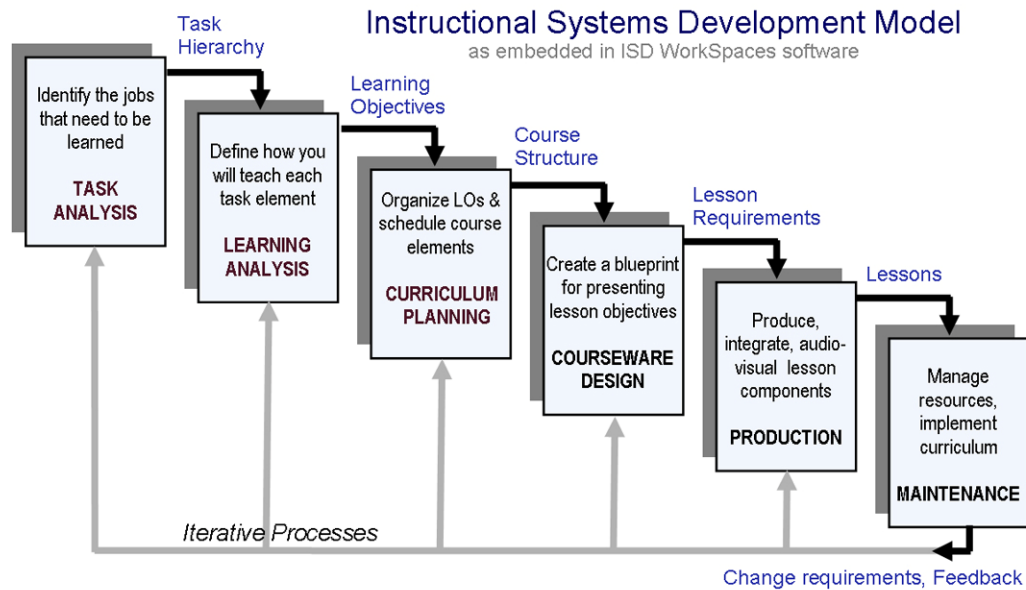


Figure 11. Embedded ISD model.

Formative evaluation is built into each stage; summative evaluation activities are included in the Production stage; evaluation activities resulting from feedback during implementation are included in the Maintenance stage. Thus these activities are not given a separate process category or main menu item. The model categories are directly mapped to the main navigation menu options in the WEB and MAP versions. The WIN treatment uses a typical tool-oriented categorization: File, Edit, Analyze, Link, Admin, and Reports.

Materials

Two types of materials were developed: those to support the operation of the experiment and those intended to provide data for analysis. Both types are contained in a Notebook application with some job aids accessible directly from the WorkSpaces application. The Map version is an exception, containing additional process support in the menu itself, information that is not available for the other treatments.

Materials providing data for analysis are the Background Questionnaire, Knowledge Pre-Test, and Post-Test. The Usability Survey provides some qualitative

information that may be used for interpreting results and to guide future efforts. Operational materials are the Research Consent Form, Welcome and De-briefing pages, Contact information, Task Instructions, and aids such as General Instructions and Search Tips. The additional resource information in the MAP treatment is accessed by central control keys (see Appendix H). These show what shared data needs to be available and prerequisite process steps for forms on each page. Labels indicate process categories and definitions for each step on hover.

Background Questionnaire

Figure 12 shows an example of a Background Questionnaire page. This information is used to assign participants to an instructional experience group (EXP-, EXP+). These questions also ask about general characteristics that may have an effect on how different groups of people use the WorkSpaces program. The responses can be used in later post-hoc tests but a thorough analysis of this data is outside the scope of this dissertation. Questions are based on demographic categories used by the U.S. Census, Openness to Experience and Conscientiousness trait items of the Five-factor model (Goldberg, 1993), common usability questions relating to computer use, and perceptual/cognitive preferences.

Figure 12. Example of a Background Questionnaire page.

Job categories were grouped by Education, Aviation, and Other. A post-hoc measure of Analytical ability (ANA) was developed based on this category. Instructions ask that participants use a checkbox to identify all types of occupation(s) they worked at for at least 1 year even if they are not currently working in that area. For selected job types, a 5-level Likert scale from Novice to Expert experience also shows. Responses for all other questions are presented as a 5-level Likert scale using radio buttons. No personally identifiable information is collected. Sex data was collected but due to a programming error, data for 25 of 145 records was overwritten before the problem was discovered.

Knowledge Pre-Test and Post-Test

These paired tests are the primary instrument to assess informal learning due to exposure to study treatments. The pre-test and post-test use substantially the same 67 questions, presented in the same order. They use a forced, multiple choice method to determine participants' alignment with conceptual relatedness, allowable

sequencing of process steps, and vocabulary use. This method was chosen to avoid the known difficulties of acquiring learner-generated graphic node-link diagrams or concept maps which are used extensively to assess the type of structural knowledge of investigated here. As Schau (2001) also points out, limitations include the time it takes to learn how to draw in this format, the lack of a universally accepted scoring system despite the number of methods that exist, and the dependency of map quality on individual skills. Quality can vary so much as to prevent useful analysis. A related method uses a partially filled in concept map, reducing the need to create the map. Examples include Fill-in-the-Structure (FITS) or 'construct-on-scaffold' (Chang, Sung, & Chen, 2001), Select-And-Fill-In (SAFI) used by Schau, et al (2001) and a completion set used by Halford & Busby (2007). This method may be appropriate following explicit instruction but prejudices the variations expected in elicitation of informal learning by presupposing the basic structure. It also requires participants to recall explicit terms so is impractical when trying to distinguish between aligned and simply related terms.

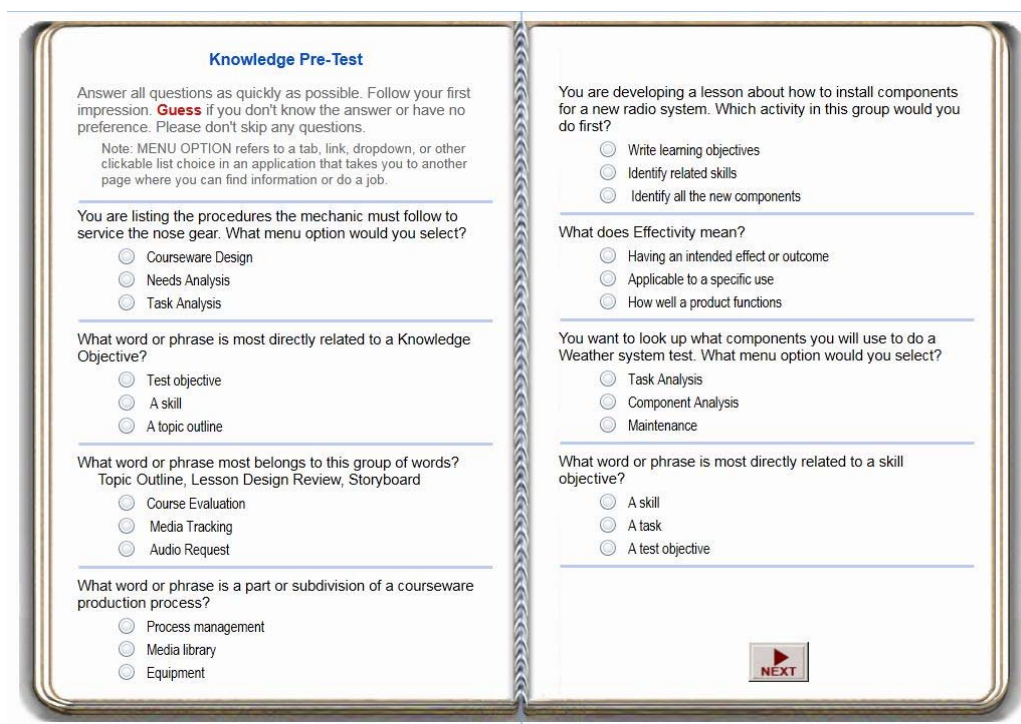


Figure 13. Text-based questions, Knowledge Check.

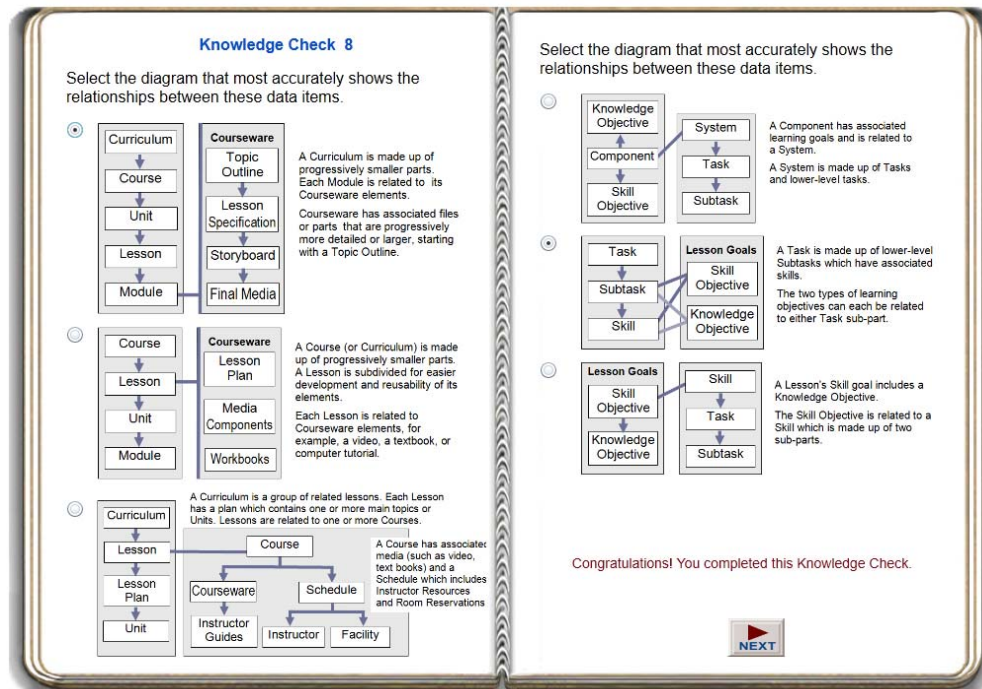


Figure 14. Diagrammed questions, Knowledge Check.

Figure 13 shows an example of the text-based approach for elicitation of the participant's conceptual model. The two final questions use a diagram response that summarizes the text-based questions (Figure 14). Since not everyone is familiar with concept maps, explanatory text accompanies the diagrams. The text-based approach used here is refined from common relatedness rating approaches (RR), concept mapping, and multiple choice approaches. Each question has a randomly sequenced set of three responses, rated as *aligned*, *related*, or *unrelated* to application use. The three main question categories match the dependent measures. The fourth category, aircraft-related questions, is used to confirm self-reported familiarity with aviation terms. Aircraft questions were omitted in the post-test. Each response is given a weighted, quadratic value to produce the score. Synonyms for *related* responses were selected from <http://thesaurus.com>. The test set was reviewed for content validity (i.e., completeness and accurate match to application model and content) and readability (are the words used sufficiently easy, and is the number of words used sufficiently low for the type of items?). All correspondences were maintained in the

database for continued consistency checks.

Structural questions addressing each main menu item reference the structural model used to design the menus and organize the application (Figure 15). Distance

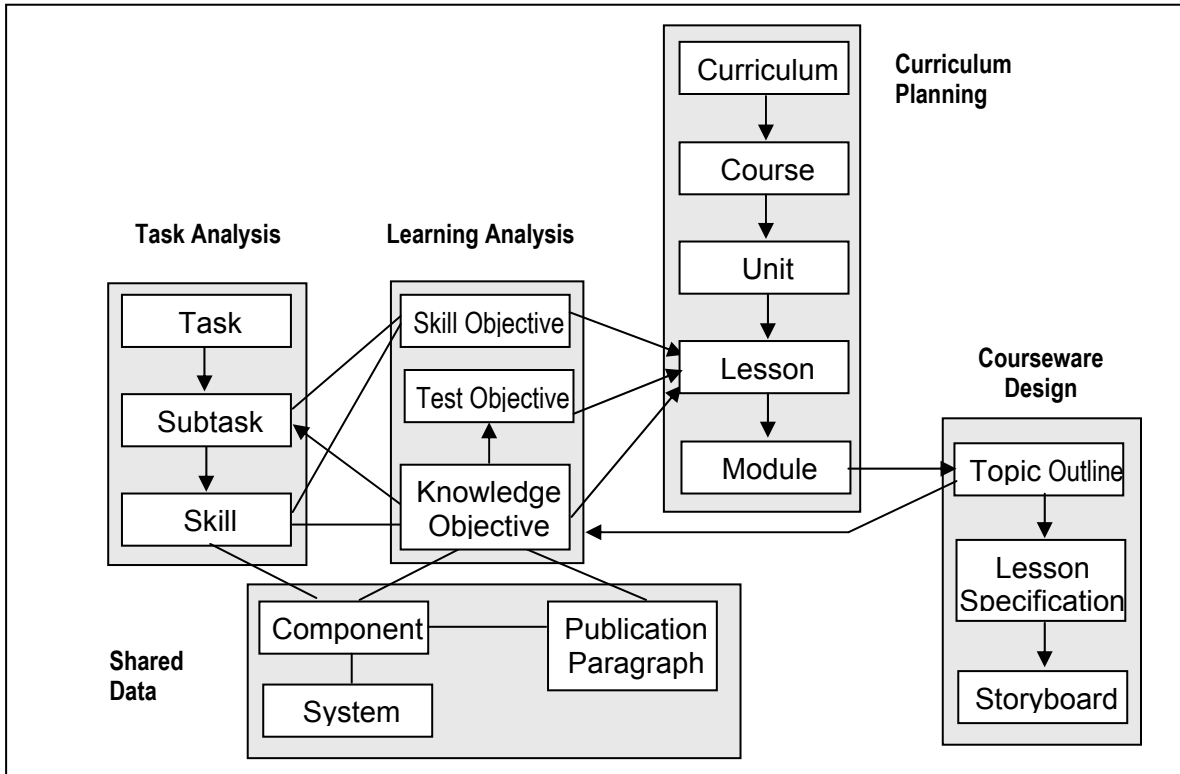


Figure 15. The Structural Model.

is measured as 1 unit when items are adjacent (connected by a line) within the same category (shown as items grouped on a shaded plate). Each intervening item and crossing a plate boundary adds a point. Lines show relationships, arrows indicate prerequisite sequence. For example, a task is a distance of 10 from a lesson spec, 2 from a skill, and 4 from a Knowledge Objective.

Relationship questions are based on these objectives:

- menu item(s) used to access pages to do [instructional task];
- the word or phrase most directly related to [word, phrase, or group of related words] (schematic distance, parts of same process stage);
- the word or phrase that most belongs to a group of words related to [concept, menu item, category];

- the hierarchical relationships of [type of category, e.g., curricular] elements or terms.

For example, the following question (#2) references words used in menu items.

What word or phrase is most directly related to a knowledge objective?

- Test objective
- A skill
- A topic outline

The *aligned* response is “Test objective” since it is adjacent and is in the same menu/process category as “knowledge objective”. The *related* response is also only 1 link away but is in a different category. The third response, *unrelated*, is separated by 2 categories plus one link.

Sequence questions reference the normal workflow and prerequisite tasks.

They are based on these objectives:

- the normal steps and sequencing of [type of instructional task or process step; e.g., instructional design, lesson development];
- prerequisite tasks for developing [courseware-related item].

Question 12 is an example:

What job must you finish before you can analyze a subtask ?

- Define a task hierarchy
- Write learning objectives
- Plan the curriculum

Vocabulary questions assess the change of implicit preferences for one word or phrase over another, based on recognition/familiarity. Here again, a movement toward alignment is an indication of learning due the influence of treatment exposure. Only first level, visible menu items are used in test items. A separate test set was developed for the WIN treatment to accommodate its intentional use of vocabulary differences. For example, WIN uses the terms Segment vs. Module, Activity vs. Skill, Operational Objectives vs. SELO.

Vocabulary questions are based on these objectives:

- the meaning or definition of [vocabulary term];
- prerequisite tasks for developing [courseware-related item].

Question 6 is an example.

What does Effectivity mean?

- Applicable to a specific use
- How well a product functions
- Having an intended effect or outcome

Figure 13 in the Procedures section shows the text-based approach and a second example of the diagram-based approach to elicitation of the participant's conceptual model.

Online Task Instructions & Aids

Instructions are accessed via the Notebook function. While the WorkSpaces application is active, a smaller version of the Notebook overlays the active page. Exploration instructions focus on navigation aspects. General Instructions help participants to use selectors and buttons for page content. Find-It instruction pages (Figure 16) in the Notebook provide a scenario as context for the job, an explanation of the target data location, and optional Hints.

Clicking the HINT button shows more explicit help. Hovering over the Notebook button with the Notebook closed shows the task target as a quick reminder.

Some early participants re-accessed the Notebook to review instructions an abnormally high number of times. A COPY TEXT button was added to instruction pages to allow participants to copy a combined form of instructions and hints to their computer clipboard and then paste into an outside editor. (This implementation of Silverlight does not permit the application to open another window or communicate with other programs.) The copied text is reworded to reduce any redundancy. The explicit but necessary nature of the instructions and their ready availability further reduced exploration and task duration. This prevented investigating navigational aspects as fully as originally planned. Appendix F lists the task instructions provided

through the COPY TEXT function.

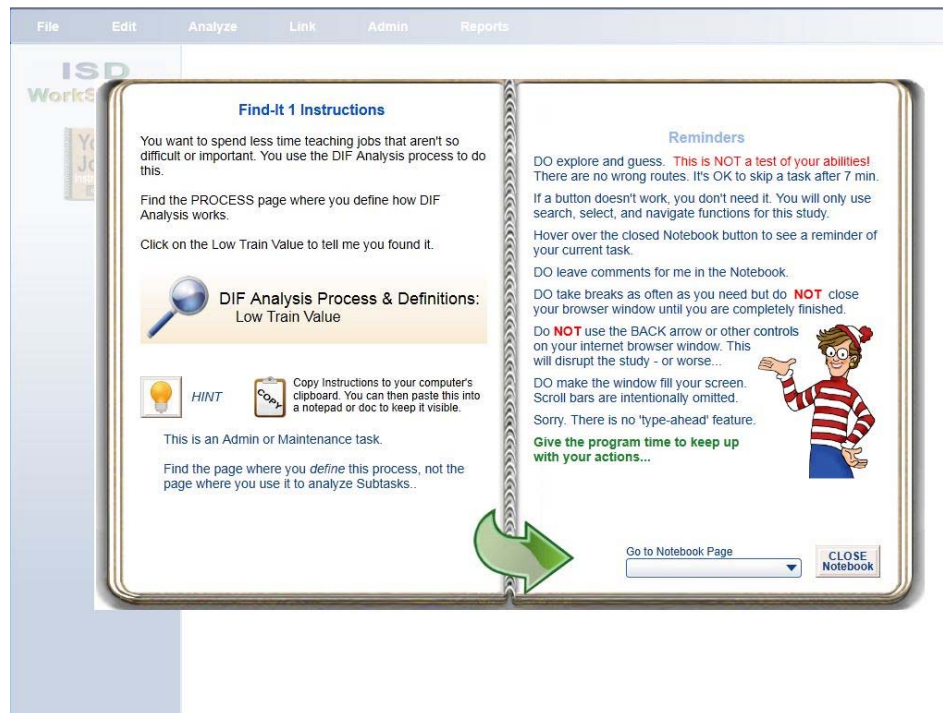


Figure 16. Example of Find-It task instructions.

The experiment does not rely on successful completion of each task, just contact time with relevant pages. Due to the perception of difficulty and increased likelihood of dropout, a Skip Task timeout option is available after 5 minutes on a task (the expert time averages 30 sec.). The message offers three options. Participants can continue to try to find the target, they can look at explicit, step-by-step instructions for finding the target, or they can skip that task and go on to the next task. If they continue, a Skip Task Button is placed on the screen until they either complete the task or choose to use the button.

A limited number of additional aids are available during task performance. Inactive buttons show a tool tips message. Search functions have a TIPS button that opens a window with instructions for how to use each contextual Search. INFO buttons explain how to use a page form for example, linking objectives. If a participant chooses a page closely related to the target page, messages may appear. For example, if the participant chooses the Shared data page where one enters new

skills into a Master List rather than the page where one links skills to related subtasks (menu text: "Assign Skills"), this message shows: "This page shows ALL Skill options. You want the page where a Skill is ASSIGNED to a specific Subtask."

The Notebook contains a page describing key navigation and page features to look for during the Exploration period, general instructions about the task Find-It process, and key reminders that show on every Find-It Instruction page. Notebook help pages are accessible at any time during the task part of the study. A full, searchable Help System could not be developed within the time available, although very low access of existing embedded aids suggest the system would not have been used enough to justify the effort. (One participant did complain of the lack of a searchable help system.)

Task Navigation Log Files

Tasks were given to promote use of the navigation controls and provide contact time with the application pages referenced by the pre- and post-tests. Task performance data captures salient features of that experience. Figure 17 shows a screen capture of the NavTracker database table where navigation path and time data is stored. Each record contains a unique record ID (NavID), the participant ID (PeopleID), study task number, access to each page, sub-page and selected controls such as the Notebook button with a timestamp. Assigned Menu and Task target data, along with a start and end task time are added later to ease analysis.

NavTracker : Table								
	NavID	People	Study	Menu	Page	Control	IsTask	RecordDate
	11372	325	16	3	TA2	DifDefButton	<input type="checkbox"/>	3/11/2012 9:49:00 PM
	11373	325	17	3	TA2	CopyToClipbo	<input type="checkbox"/>	3/11/2012 9:50:00 PM
	11374	325	17	3	CD1	PageStart	<input checked="" type="checkbox"/>	3/11/2012 9:51:00 PM
	11375	325	17	3	CD1	NBButton	<input type="checkbox"/>	3/11/2012 10:05:00 PM
	11376	325	18	3	CD1	CopyToClipbo	<input type="checkbox"/>	3/11/2012 10:05:00 PM
	11377	325	18	3	PR5	PageStart	<input type="checkbox"/>	3/11/2012 10:07:00 PM
	11378	325	18	3	RS31	PageStart	<input type="checkbox"/>	3/11/2012 10:07:00 PM
	11379	325	18	3	RS31	More	<input checked="" type="checkbox"/>	3/11/2012 10:10:00 PM
	11380	325	19	3	RS31	CopyToClipbo	<input type="checkbox"/>	3/11/2012 10:11:00 PM

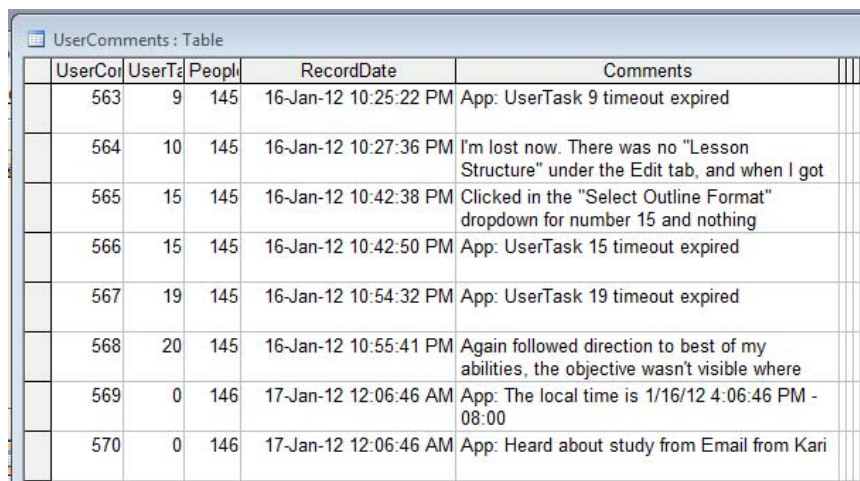
Figure 17. Example of NavTracker data log.

Usability Survey

This questionnaire is an integration of 33 common usability questions and provides an ancillary source of qualitative information. Appendix I contains a copy. This data was collected to help interpret any findings of significant effects and to help refine designs for future experiments using this application. A full review of this data is outside the scope of this experiment.

Comment Files

After completion of each task the Notebook automatically opens to the Comments and Progress page to encourage participants to leave comments (Figure 22 under the Procedures section). User comments are stored in the database with the UserID and a timestamp. The output below shows typical data from the User Comments table. This data was aggregated with the final two free-text responses from the Usability survey on positive and negative reactions to the WorkSpaces application. This data was used to help understand difficulties and attitudes but did not participate in the analysis of dependent variables.



UserCor	UserTid	People	RecordDate	Comments
563	9	145	16-Jan-12 10:25:22 PM	App: UserTask 9 timeout expired
564	10	145	16-Jan-12 10:27:36 PM	I'm lost now. There was no "Lesson Structure" under the Edit tab, and when I got
565	15	145	16-Jan-12 10:42:38 PM	Clicked in the "Select Outline Format" dropdown for number 15 and nothing
566	15	145	16-Jan-12 10:42:50 PM	App: UserTask 15 timeout expired
567	19	145	16-Jan-12 10:54:32 PM	App: UserTask 19 timeout expired
568	20	145	16-Jan-12 10:55:41 PM	Again followed direction to best of my abilities, the objective wasn't visible where
569	0	146	17-Jan-12 12:06:46 AM	App: The local time is 1/16/12 4:06:46 PM - 08:00
570	0	146	17-Jan-12 12:06:46 AM	App: Heard about study from Email from Kari

Figure 18. Example of Comments data log.

Few left comments during the study; some left comments in response to the final two Usability questions; most comments were received via email and phone conversations. The application also wrote automated messages into this table, identified by the prefix "App:".

Procedures

All participants were encouraged to look at an overview video on YouTube at <http://youtu.be/-7Q2mN1YC14>. The website <http://PhDStudy.Starcatcher.com> contained all experimental materials. Figure 3, Study Workflow and Services (in the earlier Software Description section) gives a summary of the procedural flow of the study. The materials used at each step are described in the Materials section. The appendices contain screenshot examples of each of the materials.

On entry to the site, the application displays the Welcome page with an overview of the study procedure. It notifies the user of the possible need to download the Silverlight plug-in if it is not already installed. The consent form shows on the next page, detailing the purpose and conditions of the study. Appendix A has a copy of this form; Appendix B shows the Human Subjects Review Board Approval. If the site visitor clicks on the accept button, the program assigns a User ID, downloads the data required to run the study and opens the Questionnaire.

The questionnaire (Figure 12) presents 44 background questions using checkbox and radio button responses. When all questions are answered, the program calculates the assignment of the participant to one of the two instructional experience groups, then randomly assigns participants to one of the three treatments. Participants only see information related to their assigned treatment.

The NEXT button opens the Knowledge Check (pre-test). Participants are told that they are not expected to know answers; they should answer as quickly as possible with what *feels* right or else simply guess. Using unfamiliarity/guessing and speed is a common method to reduce cognitive processing when eliciting existing mental models but is dependent on individual differences. This experiment did not control for these since it assesses general change over time, not detailed analyses of a participant's model. On completion of the Knowledge Check, participants read a brief overview of the Find-It process (Figure 19) and enter a re-entry code to use if they lose their connection. This sets a cookie that allows them to return to their last location in the study without losing their work.

The study requires contact time with the application menus and pages. To

reduce anxiety, participants have the opportunity to explore and become more comfortable with the task interfaces before beginning tasks. Figure x shows the instruction page shown to participants assigned to the MAP treatment. (The other treatments just omitted the paragraph about the MAP OPEN button.) Instructions

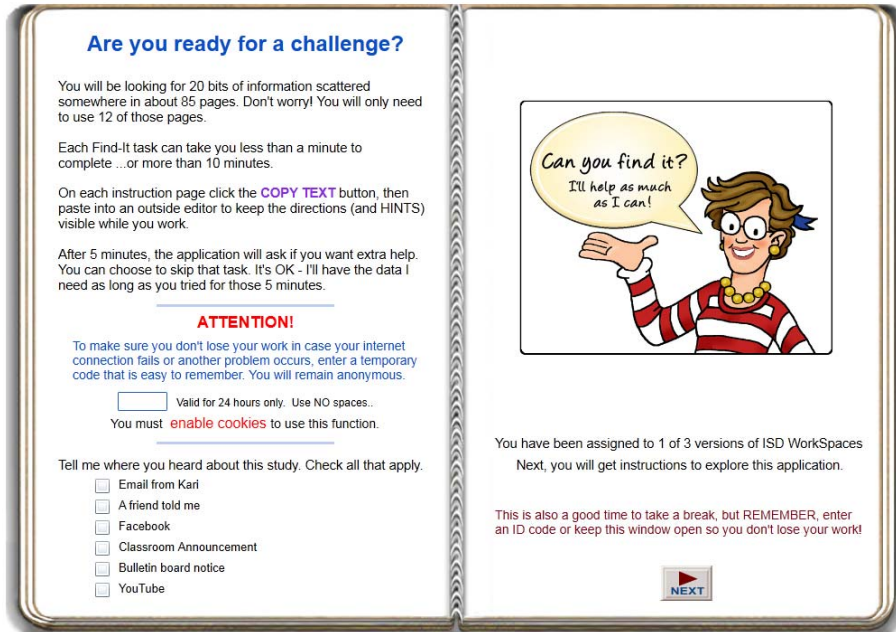


Figure 19. Transition to the WorkSpaces experimental tasks.

point out key areas that will help them do the tasks. Additional help using the page forms is available from the General Instructions page at any time in the Notebook.

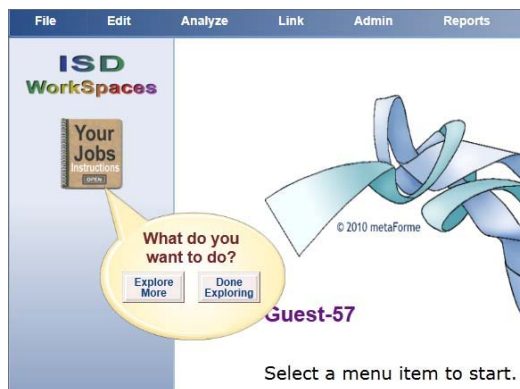


Figure 20. Done Exploring? message.

When the participant next clicks on the Notebook button, they are asked if they

are done exploring (Figure 20). If yes, the Notebook opens to the Comments and Progress page (Figure 21). This screenshot, taken after the participant clicks the “Done Exploring” button, shows the area to leave Comments and indicates the tasks completed. It overlays the active application screen.

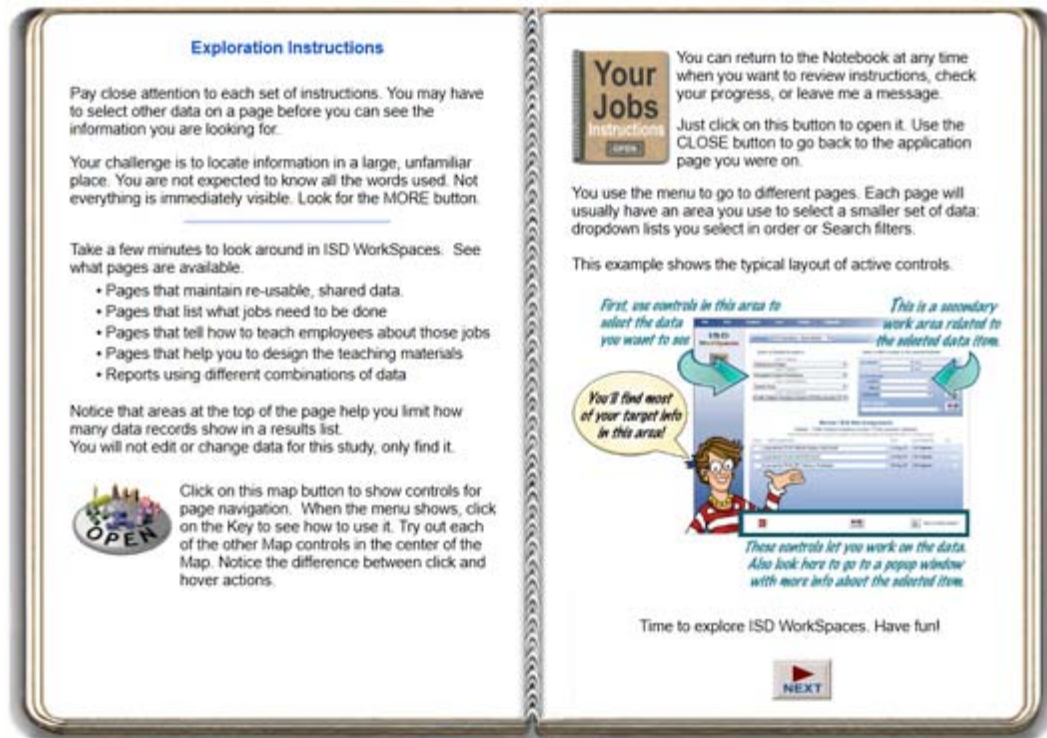


Figure 21. Exploration Instructions.

The NEXT button opens the task instructions. The green arrow highlights the NEXT button for the first two tasks only until users become familiar with its placement. Field trials showed that people had difficulty deciding what to do next

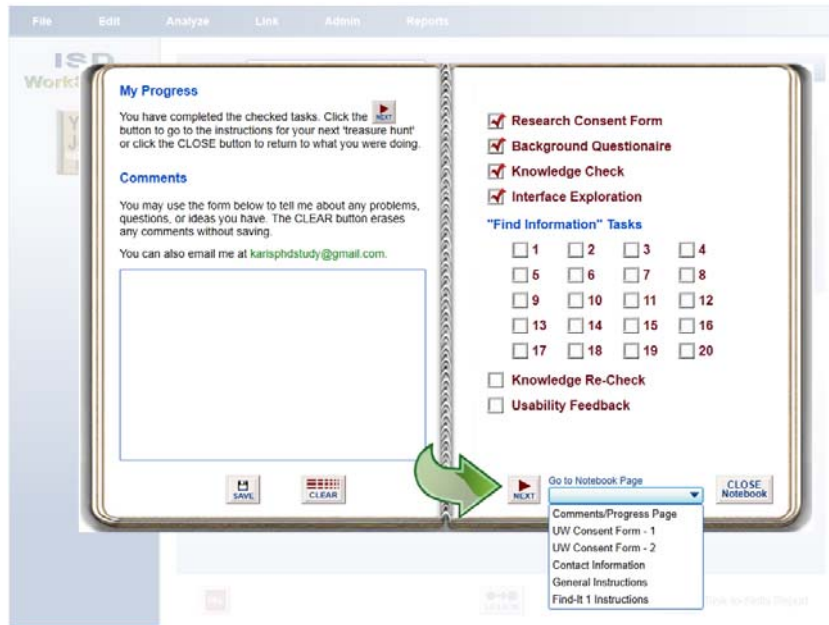


Figure 21. Comments and Progress page.

until this was added. Despite opening to this page first to encourage comments, few did so and several said they preferred to go directly to the task instructions.

The NEXT button opens the instructions for the next task only (Figure x). The magnifying glass highlights the data to find. This is the same text that is repeated when one hovers over the Notebook button in the WorkSpaces application. This example shows the additional information offered when the HINT button is pressed. Hints are initially hidden to offer the participant a greater challenge level but were viewed by almost everyone, either by clicking HINT or COPY buttons.

The process for each task is the same. Review instructions; navigate to the relevant page; use hierarchical drop-down selectors or search functions to filter larger data sets, then find the target data or scroll down smaller lists to click on the target data. As soon as this is successfully done, a “You found it” message appears. When the participant clicks the OK button, the Notebook automatically opens and instructions for the next task are available. When the last, 20th task is completed, the

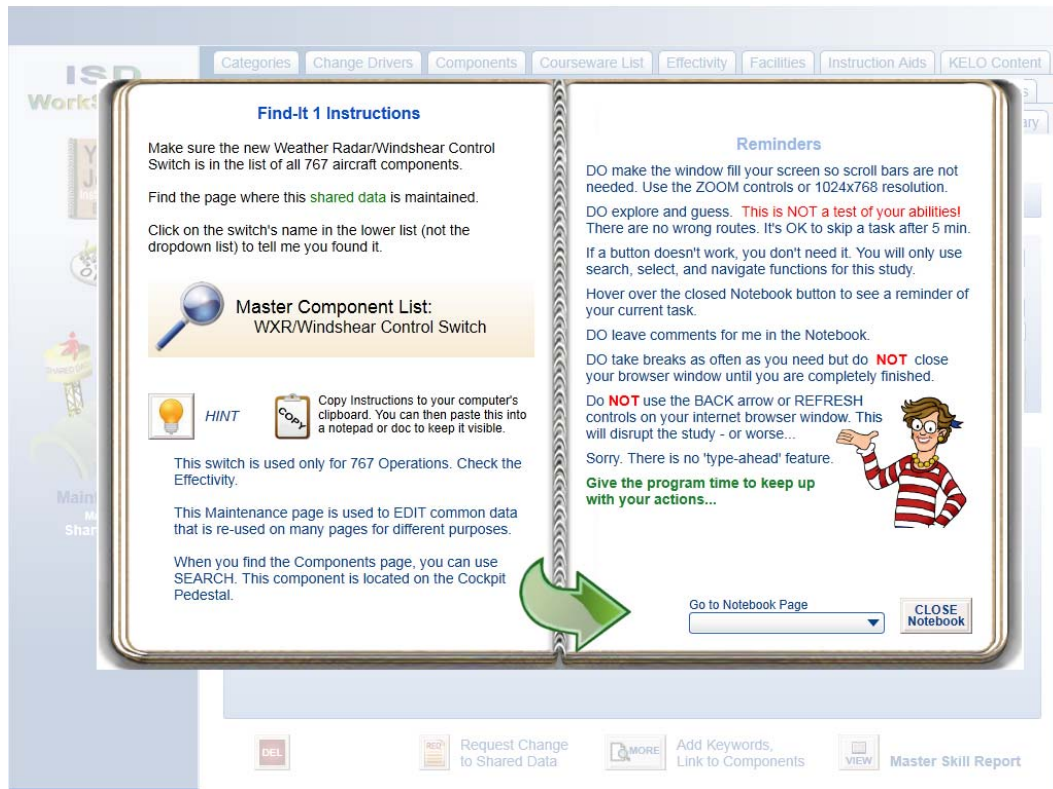


Figure 22. Example of Task Instructions.

application automatically opens the first page of the post-test (Appendix E - same as Pretest). When all questions are completed, the NEXT button opens the Usability Survey (Appendix I). When the survey is completed, the final de-briefing and Thank You page shows. The participant closes the browser window to exit the study.

The participant can take a break at any time but is asked to complete the study within 24 hours for between-subject consistency. Almost all continued straight through the study with minor breaks. If the participant had entered a code and the study was interrupted for any reason, they could re-enter at the point they left with no loss of data. These re-entries show in the log files. They could also exit the study at any point. Participants were given an email to contact me or had my phone number; about a third made contact to ask questions or make comments or report progress.

Chapter 4

RESULTS

Alignment Measures

The dependent variables were analyzed using three separate one-way ANOVA calculations with Repeated Measures (Table 6). These tests were repeated with covariates EXP and ANA to investigate the effects of these adjustments to the reported means. Summaries of test results with and without covariates are combined in the tables for each dependent measure. Insufficient completed studies reduced the likelihood of statistical significance but outcomes provide insights into opportunities for improving methods for similar, future studies.

Table 6. Experimental Factors for each Data Set.

Data Set	Time	Dependent Variable	Between-Ss Factors		N
REL	1	PreREL	MENU	WIN	18
	2	PostREL			
SEQ	1	PreSEQ		WEB	25
	2	PostSEQ			
VOC	1	PreVOC		MAP	22
	2	PostVOC			

On average, about one third of the Pretest responses matched the aligned choice, reflecting a random guess (probability = .34) or less likely, an already aligned conceptual model. For between 50 and 57% of responses, depending on treatment and measure, there was no change in post-test responses, that is, no movement toward or away from alignment.

REL outcomes

Exposure to the application without explicit training resulted in learning about the designed conceptual model of the relationships. The Time factor shows a strong, positive change in alignment ($F(1,62) = 12.24, p = .00$) when analyzed without a

covariate or adjusted by ANA ($F(1,62) = 12.24, p = .00$). The time factor is slightly less significant when adjusted with EXP ($F(1,62) = 5.8, p = .02$). This learning does not appear to be correlated with a specific menu type at an alpha of .05 since all menu types improved about equally (Figure 24). Variability in test scores remained about 10 points for both the pre-test and post test despite the spread between groups. The improvement between tests for the WEB group was slightly less than for the other two. WIN participants with higher analytical scores may score slightly higher than others in that group whereas higher EXP rating may benefit the MAP group.

Table 7. REL Statistics

Test	Covariate	Source	SS	df	MS	F	Sig.
Within Contrasts	None	Time	4415.055	1	4415.055	12.240	.001
		Time*Menu	22.266	2	11.133	.031	.970
	EXP	Time	1283.708	1	1283.708	3.569	.064
		Time*Exp	425.366	1	425.366	1.183	.281
		Time*Menu	54.242	2	27.121	.075	.927
	ANA	Time	2140.876	1	2140.876	5.895	.018
		Time*Ana	209.258	1	209.258	.576	.451
		Time*Menu	56.156	2	28.078	.077	.926
	Between Effects	None	Menu	2079.479	2	1039.739	1.343
EXP		EXP	1089.075	1	1089.075	1.416	.239
		Menu	2061.540	2	1030.770	1.340	.269
ANA		ANA	352.031	1	352.031	.451	.505
		Menu	1744.166	2	872.083	1.116	.334

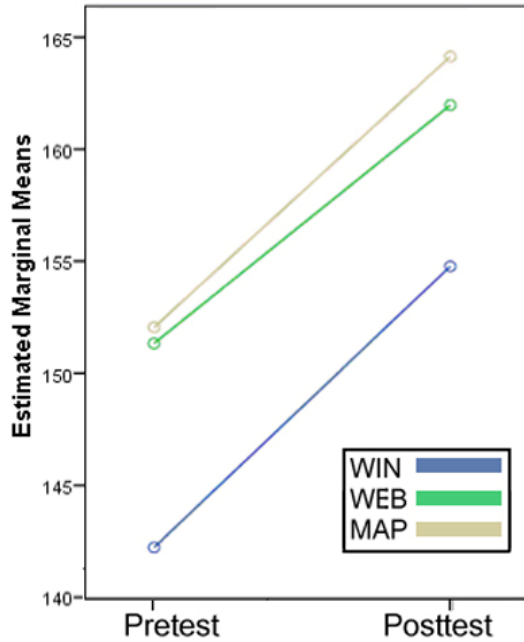


Figure 24. Comparison of Menu Types for REL.

SEQ outcomes

For a directional hypothesis, one-tailed, Time also approaches statistical significance for SEQ ($F(1,62) = 2.492, p = .06$) and improves slightly when the means are adjusted for the ANA covariate ($F(1,62) = 2.638, p = .05$). Time is not statistically significant using the EXP covariate. Figure 25 suggests an interaction of Time and the WEB menu.

Table 8. SEQ Statistics

Test	Covariate	Source	SS	df	MS	F	Sig.
Within Contrasts	None	Time	365.309	1	365.309	2.426	.124
		Time*Menu	500.697	2	250.349	1.662	.198
	EXP	Time	65.723	1	65.723	.430	.514
		Time*Exp	13.458	1	13.458	.088	.768
		Time*Menu	468.505	2	234.253	1.533	.224
	ANA	Time	401.318	1	401.318	2.638	.109
		Time*Ana	57.874	1	57.874	.380	.540
		Time*Menu	541.569	2	270.784	1.780	.177

Between Effects	None	Menu	400.230	2	200.115	.491	.614
	EXP	EXP	57.856	1	57.856	.341	.561
		Menu	666.163	2	333.082	1.964	.149
	ANA	ANA	84.097	1	84.097	.497	.483
		Menu	688.261	2	344.130	2.035	.139

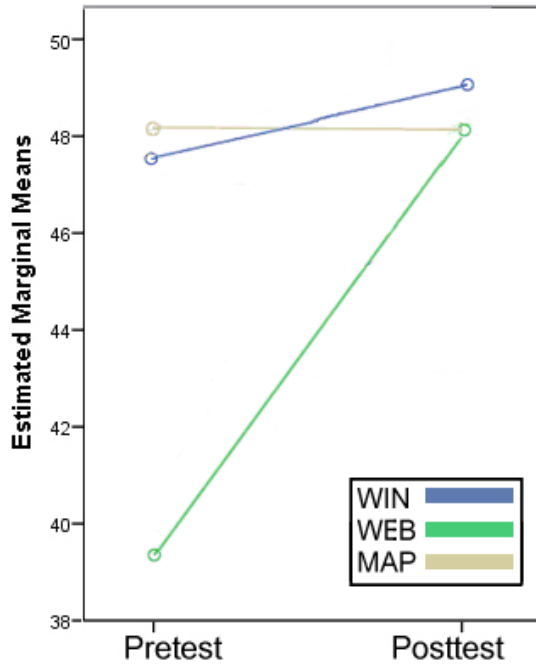


Figure 25. Comparison of Menu Types for SEQ.

VOC outcomes

The VOC measure also shows a strong improvement in alignment scores ($F(1,62) = 38.5, p = .00$) with no change when adjusted by covariates EXP and ANA. There is very little variability in pre- and post-test scores between groups and no menu type interaction. Post hoc comparisons suggest there may be some positive effect of ANA for the WIN group and a slight negative effect of ANA on the WEB group but this lacks sufficient significance in the current study.

Table 9. VOC Statistics

Test	Covariate	Source	SS	df	MS	F	Sig.
Within	None	Time	9301.427	1	9301.427	38.503	.000
		Time*Menu	123.471	2	61.736	.256	.775
	EXP	Time	1886.891	1	1886.891	7.684	.007

Contrasts		Time*Exp	419.294	1	419.294	1.707	.196
		Time*Menu	92.375	2	46.188	.188	.829
	ANA	Time	5607.317	1	5607.317	22.396	.000
		Time*Ana	126.235	1	126.235	.504	.480
		Time*Menu	54.102	2	27.051	.108	.898
Between Effects	None	Menu	1851.954	2	925.977	.948	.393
		EXP	76.606	1	76.606	.173	.679
	ANA	Menu	433.881	2	216.940	.490	.615
		ANA	4971.388	1	4971.388	13.721	.000
		Menu	46.182	2	23.091	.064	.938

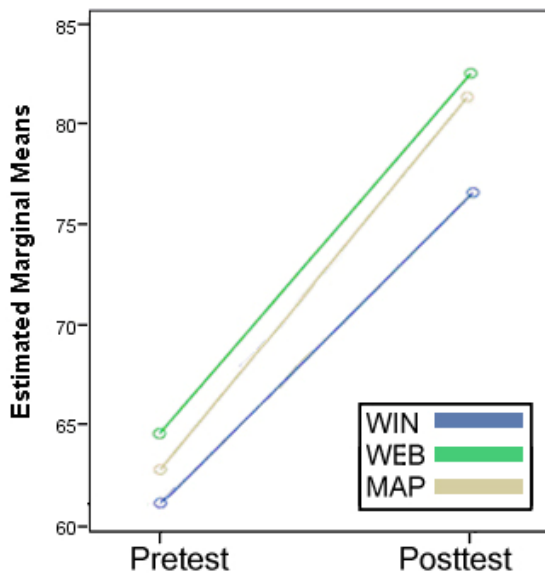


Figure 26. Comparison of Menu Types for VOC.

Task Performance Measures

Outcomes are dependent on the quality and quantity of contact time with the treatments. Data used to characterize this performance includes the count of pages visited, the number of tasks completed and the number of timeouts, time-on-task with a comparison to time spent exploring, and a comparison of this data for the first set of 10 tasks and the final 10 tasks. Figures 27-29 show individual examples of this data. Overall, the WIN group fared the worst, the WEB best. WIN had the highest dropout rate, 45%, compared with the WEB at 32.5%. (MAP was in the middle at

40%). On average WIN users completed the fewest tasks before quitting: 4.6 compared to 7.5 for WEB and 6.6 for MAP. WIN users also navigated the fewest times overall but times between task set decreased the most. Results of this efficiency and perceived difficulty perspective are consistent with other trends.

The NavTracker logged 11,998 non-unique page visits for the 153 participants who used WorkSpaces. Navigation ranged from one page visited (10 people) to nearly 500 (2 people). The two highest navigation counts were 498 for a completed study and 483 for an incomplete (14 tasks done). Those that completed the study had an average navigation count of 132.6 page visits with high

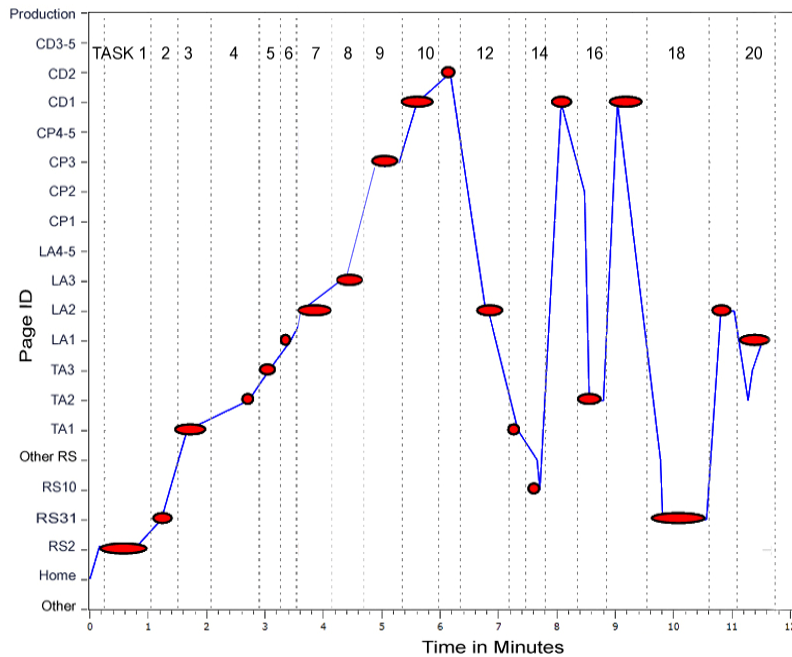


Figure 27. Task Timeline, Expert model.

individual variability. NavTracker plots capture this performance data. Red ovals locate the target pages; their width shows time-on-task (end time as vertical dashed lines). Blue lines connect navigation points; a flat line is time spent in the Notebook (usually reading instructions or taking a break). Figure 27 shows the expert path with a time-on-task of 9.9 minutes, no exploration time, no breaks, and no timeouts.

Figures 28 and 29 show examples of other paths and skipped tasks.

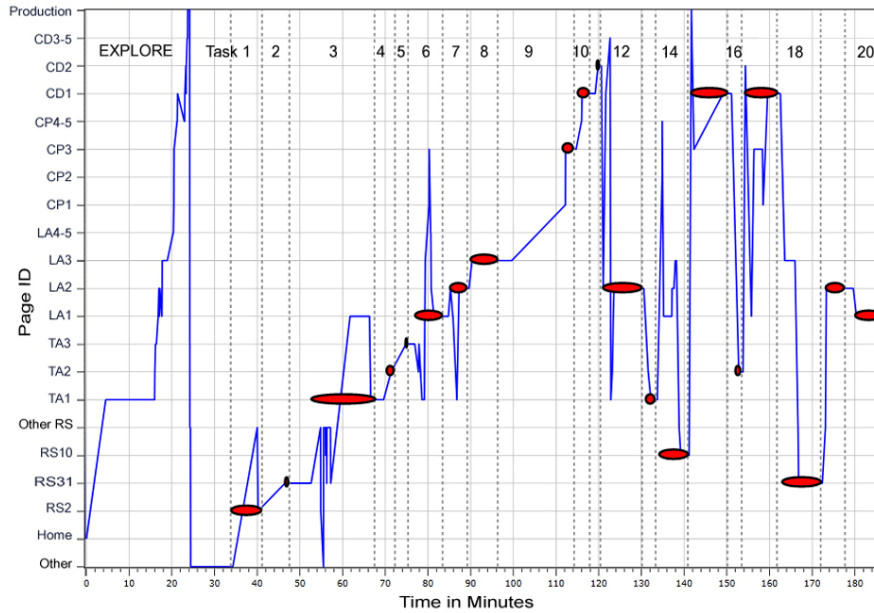


Figure 28. Task Timeline (Participant 41).

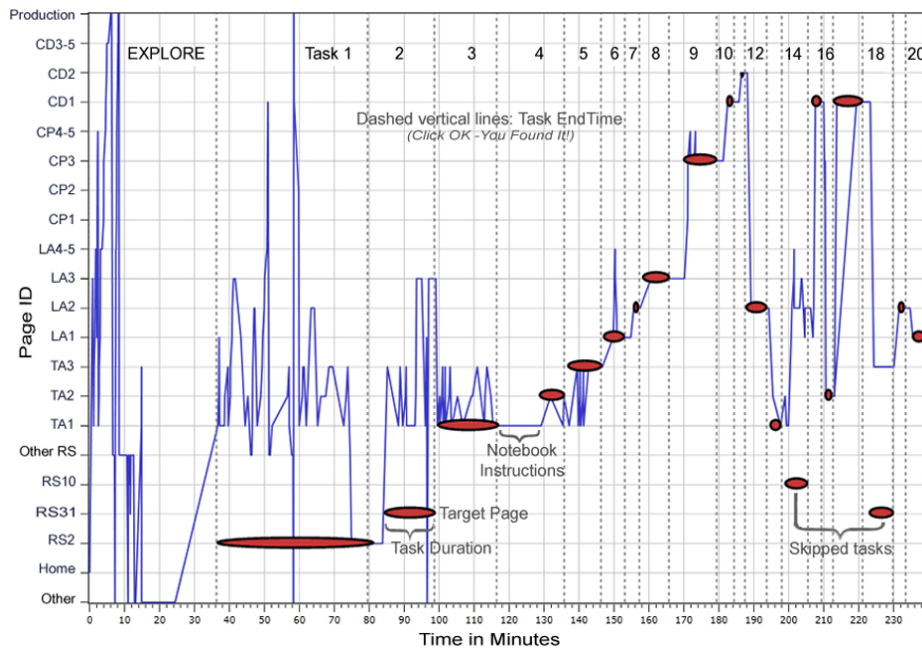


Figure 29. Task Timeline (Participant 303).

In the example of participant 303, the timeout message for the first three tasks displayed but he chose to continue until he found the targets. However, on tasks 14 and 18, he did not find the target page and eventually did skip those tasks.

Figure 29 shows the number of average number of page visits for each task

overall and by menu. The average declined over time for all treatments. The average number of pages visited were WIN, 106.5 (range 51 to 169); MAP, 132.3 (range 31 to 498); and WEB, 158.7 (range 33 to 397). Participants in the WEB group tended to navigate more frequently. Excessive navigation (87) by one person who then quit the study skews the WEB average on Task 14. The navigation count for those assigned to WIN and WEB menus who finished the study had 4% lower counts than those that quit. Those assigned to MAP who finished had 8% higher navigation counts than those who quit.

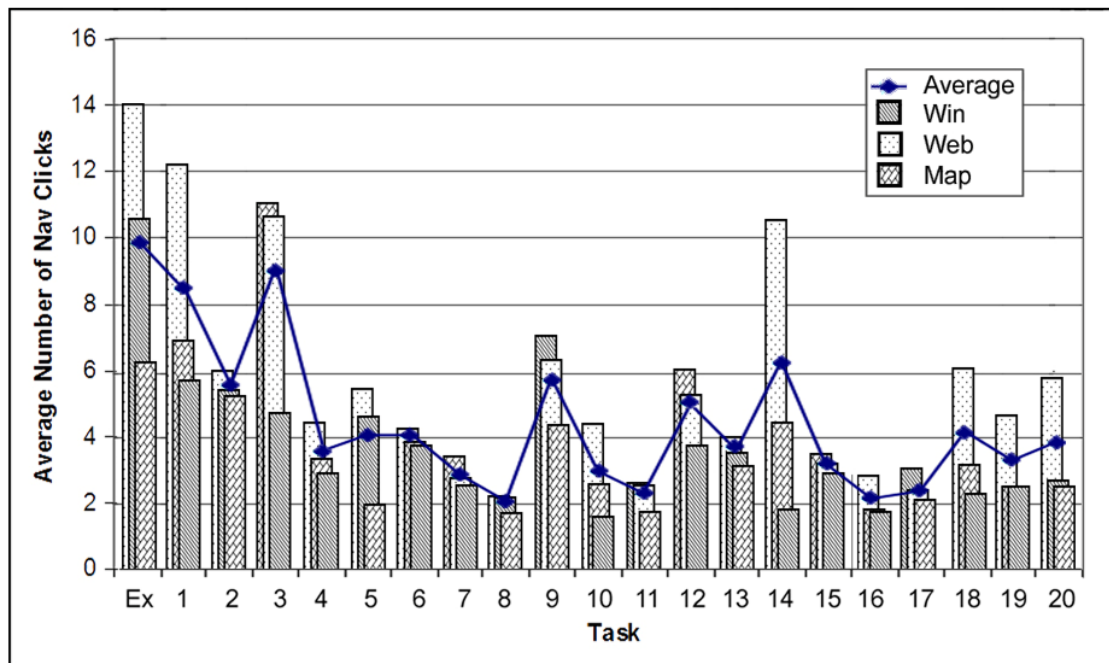


Figure 30. Navigation Frequency by Menu and Task.

Task Completion and Timeouts

Task completion counts, like task duration, are used here in combination with other data to help interpret alignment results. The number of timeouts also correlated with perception of task difficulty and drop-out rates; traits like extrinsic motivation appear to influence early departure. Of 155 who began the task part of the study, 65 completed all twenty tasks. Most who reached the midpoint continued (Table 10).

Table 10. Dropout rate. Number of participants completing each task.

Task	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Total Done	119	113	103	95	91	88	86	82	77	75	72	70	70	69	69	67	67	67	67	67	67	65

52.8% of all participants (whether or not they finished the study) exceeded five minutes on tasks in the first set. This dropped to 26.1% for the second task set. For those participants who completed 10 tasks or fewer, rates were very high, 92.6% overall with 100% on 6 of those tasks and no task having lower than a 60% timeout rate. Table 11 shows rates for those who continued into the second set of tasks. This rate dropped overall with an exception for Task 14 which was perceived as very difficult. For the final task, the rate was only 27.3%. Timeouts indicate that a person spent sufficient time on task; finding the target data helped with motivation to continue but was otherwise not relevant.

Table 11. Timeout Rates by Task Set.

<i>Nr of Tasks Done</i>	<i>Task Set 1 Timeout Rate</i>	<i>Task Set 2 Timeout Rate</i>
12	50%	41.7%
14	100%	71.4%
19	60%	31.6%
20	53.7%	27.3%

Exploration Time and Task Durations

Time-on-task shows an overall improvement between task sets but is not a precise measure. Uncontrolled factors also contribute to duration, for example, breaks, additional exploration, and inattentiveness. Figure 31 shows the average time for each task contrasted with the expert time. Variations in the expert time are mostly due to the time required to select the correct data from page content, not navigation time. Participant times appeared to be influenced by other factors.

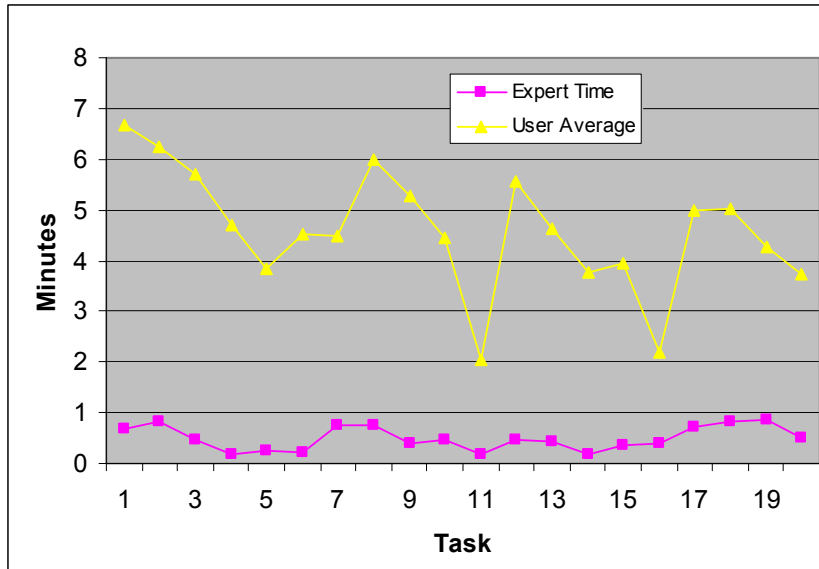


Figure 31. Average Time Spent per Task.

Total time for completed studies ranged from 20 minutes with an average time on task of 1 minute (young female) to 177.5 minutes with an average time on task of 9 minutes (middle-aged male). Although both were assigned to the WEB menu, there is no statistically significant correlation between age, sex, or menu for a time-on-task measure.

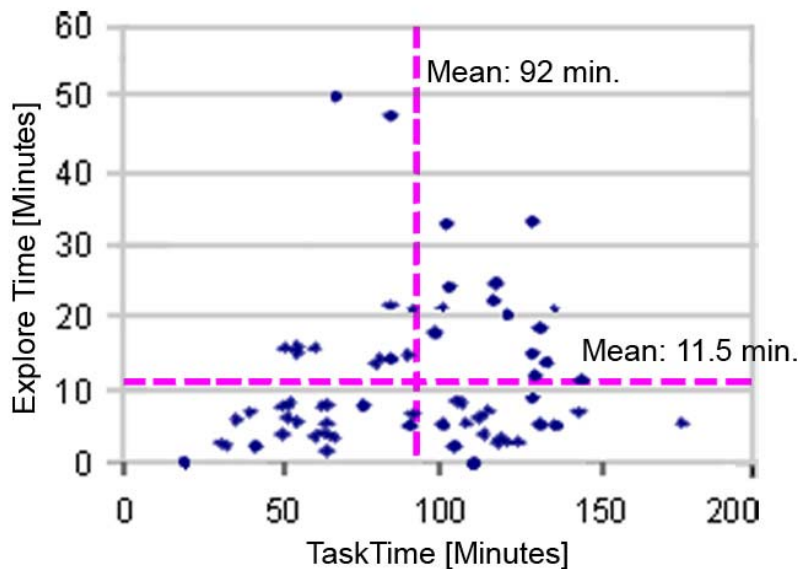


Figure 32. Comparison of Explore and Task Times.

Task Set Comparisons

A comparison of the first 10 tasks to the second 10 tasks shows substantial improvement in learning to use the application for all treatments (Figure 33). This learning reduces the cognitive load imposed by an extensive, complex, and unfamiliar tool and is a prerequisite for identifying any trends in incidental learning of the embedded conceptual model.

For completed studies, the average time spent on tasks in the initial set was 5.4 minutes (range: 4.2 - 6.9). This was reduced by 22% to 4.2 (range: 2.2 - 5.5) for the second task set and is statistically significant for time ($F(1,61) = 32.1, p = .00$) but does not interact strongly with menu type. Both the WIN and WEB groups made equivalent improvements with less of a time reduction by the MAP group.

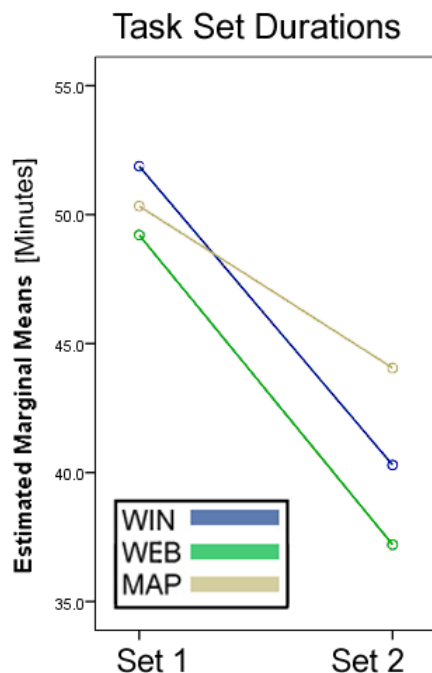


Figure 33. Comparison of Task Set Times.

Qualitative information

Comments were not required during tasks nor in the Usability survey; few used this opportunity. There were 113 User Comments logged by 25 individuals (85% of

whom completed the study) and a dozen sets of direct communications with the investigator. Of comments captured online, roughly equal numbers came from persons assigned to the WIN and WEB treatments; only 13% from MAP. 42% of all comments came from just 3 individuals who did finish. A third of participants declined to answer the final two free-text questions on the Usability Survey. Of direct communications, participants either wanted to ask procedural questions, questions about a specific task, or to explain why they didn't finish. Direct replies to participants by the investigator either offered set-up troubleshooting or, during the task phase, provided the same procedural information as available in the generally unread online help materials. Most common replies were to direct attention to parts of the instructions by asking, "What does xx say, did you look at xx?". Providing continual encouragement seemed sufficient in other cases.

The most common topics referenced frustration and perceived sense of difficulty, technical issues, and design preferences. Many had a strong emotional component. 17% of responses were positive, commenting on their progress or reflecting a sense of accomplishment and pride in persistence and participation. For example:

- "I just followed directions, didn't worry that I didn't really understand – it was easy",
- "Tasks seem to be getting easier. Answer is almost given from the start",
- "I have a good idea about how to look for information. The hints are helpful",
- "I completed the task within less than 5 minutes, well I read the hint but I'm happy I made it",
- "I had some problem with this one at first and I read the hint but after a while understood what I should do and how".

Another had a positive reaction but disliked going to the Comments page before the next task instructions:

- "I feel I am more familiar with the interface after the first two tasks. I am able to find the information that I need to accomplish the task in a short

time, but when I was ready to leave this task, clicking next did not take me to the next task directly.”

Some were neutral:

- “Note: although i'm clicking "Copy" on each task screen, that's just to provide me with a pre-copied security blanket. I usually don't read them”,
- “I found that wndshear control thng in time but i dont know how to verify it and tell u that ifound it”

60% of the comments were negative, generally related to the perceived difficulty which was most often attributed to poor design and implementation.

- “This "game" has totally exceeded my patience/frustration tolerance “,
- ” I've been at this for over 3 hours with no breaks. I have to work tomorrow. I should have been in bed an hour ago. :- (“ - from one who completed the study,
- “NO WAY. You can either give me a human being who can show me what you need or FORGET ABOUT IT. There is no way I would ever ever ever spend my time doing this for anyone (unless of course it were for a great purpose like ending WAR on planet earth)” - from one who finished only 4 tasks.

70 % of the comments referred to the perceived difficulty; most quit when frustrated or impatient with the need to pay close attention. Others expressed relief when they had less difficulty as they progressed. Comments included:

- “Easy tasks make for good motivators”,
- “Weeeeelll let's see... it's been more than an hour of FindIt time, and i'm beginning to get frayed around the edges (and thru the middle)... i haven't got much faith that i'll make it through all 20, but we'll see...”,
- “I did find the right page but i couldn't find the required subtask in the drop-down menus”,

One participant spoke at length about why she did not complete the study. She didn't feel it was too difficult but rather that she did not like the way it made her feel. As a therapist she was used to being able to build a coherent picture of new

information and activities rather quickly. After a few tasks, she lacked this sense and felt she was failing. She was uncomfortable with that feeling and saw no personal benefit to continuing. Similarly, another wrote, "I find that unlike learning other tasks or skills from zero, nothing seems to build on the foundation of the preceding lesson or task."

A few were unusually persistent, using their restart codes repeatedly to keep trying. For example, "Salutations kari, I am using the Opera browser (v 11.60) and it cannot proper load the Interface Exploration page. I will try again using Internet Explorer v9." Several more emails indicated that he tried his computer at work (didn't allow access) and then yet another before taking the study. Another reported multiple attempts since she was unfamiliar with computers beyond email and didn't know how to resize her screen size as recommended. Both finished.

Of the 32% which reported technical difficulties, the study application was responsible for only two. These issues had no solution within the study time-frame and prevented participation. During the Questionnaire, a few laptops did not allow re-sizing of the display to fit the screen and removed scroll bars despite programming to the contrary. There were no such reports when using desktop computers. Of those that did properly manage the screen, some wide-screen laptop configurations overrode task instructions to place window content starting in the top, left corner of the browser window and centered the page instead and/or removed scroll bars. One commented, "The first "explore" page speaks of menu items. However, no "menu" seems to exist (unless it's above my visible window). The browser window isn't letting me "grow" it, and ctrl-shift-(plus/minus) seem to have no effect." This obscures the WIN menu so those users believed there to be no menu.

The remainder of bug reports were checked and found to be user errors, due to inattention to either the environment or to task instructions. For example, users were repeatedly reminded to use only WorkSpaces controls (e.g., the NEXT button), not browser controls to avoid known Silverlight limitations yet several did so and reported 'bugs'. The majority of other performance issues were clearly due to inattention. One reported, "Again, the Answer doesn't match the page. There is no 'Is

Subtask?' checkbox." This participant saw the word 'Subtask' and assumed the target was the 'Subtask' Page, superficially matching only the words (very common among all participants). When the target 'Is a Subtask' checkbox was not found on this page, he did not explore further but assumed it was a program error despite the checkbox appearing next to the previous task target; it is also referenced in the hint.

Another reported, "I foud [sic] the answer, but did not know that I had to click knowledge statement to end this task." In this case as in others, the logs show that they had indeed found the answer, clicked the OK button, gone to the Notebook and closed it again to return to the same page. Several had already forgotten their most recent actions and did not realize that they were already on the next task.

People commonly commented that the instructions were wrong, incomplete, or misleading. When asked to review the instructions, they admitted to having scanned them too quickly, to having skipped parts, or not reading carefully. A typical example is this comment: "The instructions tell me to go somewhere that says it is not needed for this study - very confusing." Instructions state:

"The addition of a pilot task makes it necessary to specify a new performance condition that is not currently available in the program: "by touch". Find the page where you can add this condition to make it available to other pages for re-use. Click on the Request Change button for this **Shared Data** to tell me you found the correct page section. Hint: This data, like cues and standards, is shared by **Learning Objectives** statements."

Two earlier tasks had exposed the participant making this comment to this category. She navigated 43 times for this task, trying all other menu items up to 3 times before trying *any* Shared Data page as directed in the instructions. Rather than clicking on the tab labeled 'Learning Objectives', she skipped the task to go on to the next. It was also common to arrive at the target page and leave again so quickly that one could not actually review page contents to assess whether it was a possible target.

During direct conversations where I could ask participants to review the instructions, they admitted to having scanned instructions too quickly, to having skipped parts, to not reading carefully, or simply not understanding. For example:

- “Sorry, got distracted on that last task (#10)“,
- “When I originally clicked on "Shared Data," I got a message that the page was not active. It never occurred to me to try a different tab on that page. orry - not obvious”.

Usability

Although a full analysis of usability differences is outside the scope of this dissertation, the last two questions of the Usability survey highlight the influence of individual differences; comments show extreme ranges from positive to negative with none predominating. Comments for WIN and WEB are similar with one exception specific to the design of the WEB accordion-style menu. Depending on computer and internet connection speed, the menu opens and closes too quickly (or slowly) on hover and the submenu does not update if one moves too quickly off the menu. These were programming issues that could not be resolved in the time available. Comments about this issue include:

- “slow to respond. Some groups did not expand until clicked twice. “,
- “The position of he menu, the sensitivity at which the sub menus moved was unpredictable and annoying” ,
- “The menus shifted WAYYYYYY too much when the mouse was passing by. They sould have been expandable/ closable. Not explode and collapse with little to no effort”.

The comments on what participants liked most and least about the navigation method they used provide little design guidance for which application aspects people found most useful. It is also clear that most have not used such a broad, integrated program before. A wide variety of data is required to perform the tasks; menu items are how one accesses these data entry pages yet many commented that there were too many menu items. For example:

- “way too many options (drop down menus, etc)”,
- “It was very dificult and confusing to me. I spent over one hour just geting the firt four done. lthought that if I worked throughtit I could them begin

to understand the organizations and how the program worked. Wrong. I spent a total of over 6 hours finish”.

There were complaints about the unfamiliarity of vocabulary, expected since every corporate culture and academic discipline has its own jargon:

- “None of the titles of the menu structure items are from the standard english dictionary of common terms used in day to day conversation“,
- “Term definitions were so non-intuitive”,
- “The terminology” (feature liked least).

WIN menu comments generally referenced categorization, its primary characteristic. Comments include:

- “It was pretty easy to understand “,
- ““there was nothing remarkable either good or bad about the navigation”,
- I don't know, maybe they were a bit dull, but that was good because then it was easier to stay focused”,
- “The subtopics beneath "file" "analyze", etc. were easy to navigate through and on the whole things were in the subcategory I expected them to be in”,
- “Organization of topics and subtopics meaningless... seemed as meaningless and arbitrary at the end as at the beginning of the exercise”.

For the WEB menu, participants commented on structural and the technical issue previously described. They were troubled by the vocabulary and liked the visibility of submenus. Comments include:

- “That you can see the options before you click on them”,
- “They implied some structure to the content, and even though the titles of that structure were strange, having this implied structure helped navigate a bit”,
- “It was easy to follow and find my way around”,
- “There was no hints about what a menu page did, beyond its title. A "Help" function would have been useful”.

For the MAP menu, comments focused more on the unique visual presentation and additional resource information which was generally disliked although it was user-controlled. Comments include:

- “The Map is pretty and it is easy to remember and to use”,
- “The initial menu and some of the cues and spatial organization it used, implicit loops of described functionality” – from a computing professional,
- “The pop-up explanations” (feature liked best),
- “The graphics and color design” (feature liked best),
- “I liked the visual 'city' presentation that popped up”,
- “however, I don't think of "maitainance" I think of Hangar, I don't think of (insert what it is here) I think of the Westin Towers. I didn't realize until the end that the names of the map structures were very important and what the skill assesment part was refering to”,
- “more information than necessary”.

Cognitive Load Revisited

The results strongly suggest that cognitive load effects masked more significant results. To further investigate this impact, a subset of the population was chosen who exhibited less anxiety. Criteria for participant inclusion were defined to operationalize cognitive load in this context:

- They would have fewer timeouts than average (less than 4 compared to 8.3 for all participants).
- They would have no more than one task where they did not navigate but waited for the Skip Task button to be available.
- They would finish all 20 tasks in less than the mean time (92 minutes) for all participants (see Figure 32. Comparison of Explore and Task Times).

The first two criteria determined that the task time cutoff would be 60 minutes or less. 22% of participants met these criteria, producing a conservative subgroup of 14. None in this group had any comments suggesting difficulty. The populations of

the two groups have essentially the same proportions for instructional experience: 23% of the full group vs. 21.4% for this sub group. Table 13 shows the percentage of the populations assigned to each treatment for the Low Difficulty subgroup and the group as a whole.

Table 13. Comparison of Low Difficulty Group Composition

	<i>WIN</i>	<i>WEB</i>	<i>MAP</i>
Low Difficulty (14 members)	14 %	50 %	36 %
All (65 members)	27 %	38 %	34 %

Although participants were initially assigned in equal numbers, the WIN treatment in general had a lower percentage of people completing the study. This number dropped even more for the Low Difficulty group - only 2 qualified. (On average, the full WIN group spent longer at tasks than others.) This alone indicates this menu type was more difficult and is consistent with the initial prediction that this would be the least effective design to influence one's conceptual model. The WIN treatment was therefore not considered in the following ANOVA repeated measures test. The VOC measure provided no new information and was also excluded.

Table 14. Within Contrasts, Low Difficulty Group

<i>Source</i>	<i>Measure</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Time	REL	1827.235	1	1827.235	5.786	.029
	SEQ	.450	1	.450	.003	.954
Time * Menu	REL	177.013	1	177.013	.560	.465
	SEQ	572.450	1	572.450	4.367	.053

Table 15. Between Effects, Low Difficulty Group

<i>Source</i>	<i>Measure</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Intercept	REL	874525.901	1	874525.901	868.919	.000
	SEQ	89914.050	1	89914.050	556.970	.000
Menu	REL	57.235	1	57.235	.057	.815
	SEQ	338.939	1	338.939	2.100	.167

Figure 34 shows the relative effects of the menu type on the alignment scores when controlling for difficulty. Results for REL continue to show learning changes over time but the MAP treatment does less well for this smaller group than before. The within-group contrast for SEQ with this low difficulty group ($F(1,1) = 4.37, p = .05$) is stronger than for the full group. This two-tailed p-value now reaches an accepted level of significance. The smaller MAP group now shows a marked decrease in SEQ alignment whereas the full MAP group showed no change. These results confirm the

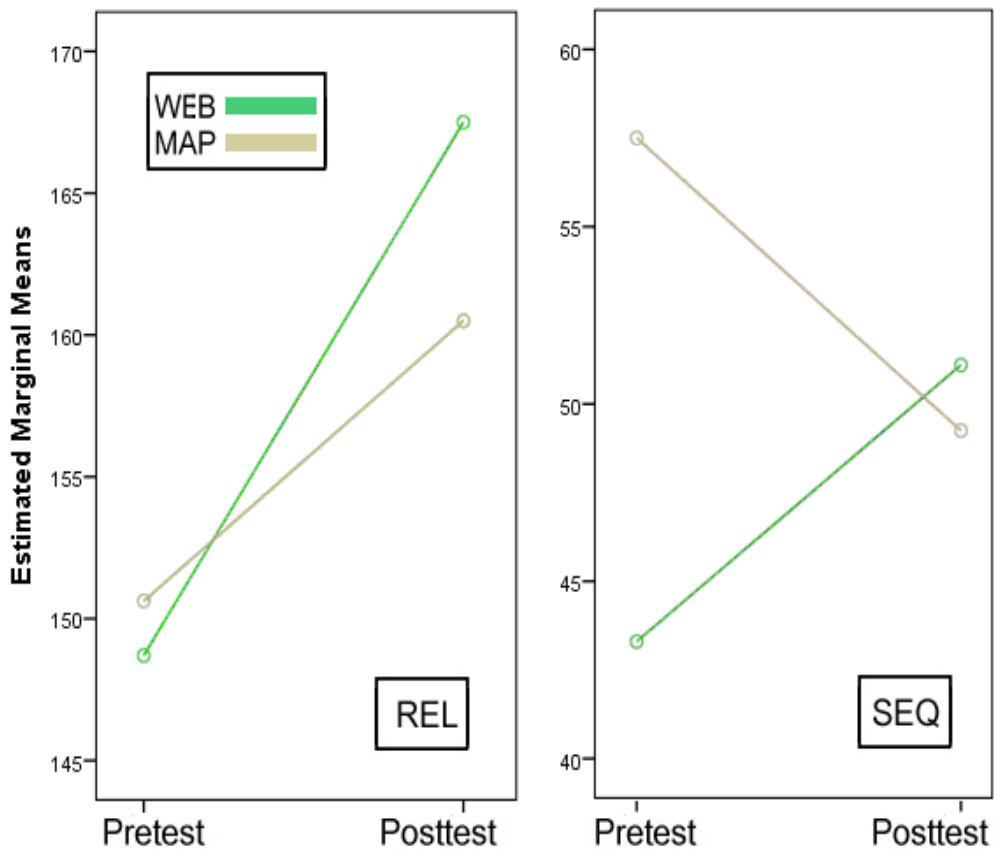


Figure 34. Comparison of Menu Types, Low Difficulty Group.

hypothesis that difficulty factors affected the statistical outcomes for SEQ and also appear to have some effect on REL.

Contrary to the hypothesis that the MAP menu would show the greatest alignment across measures, the WEB group performed better overall. Fewer of its members dropped out, perceived difficulty was lower, and it was the only treatment to

show a statistically significant time*menu interaction. Given the consistency of trends, better control of sources of interference would likely lead to a clearer correlation between alignment scores and menu types than this study was able to demonstrate.

Chapter 7

DISCUSSION

The primary focus of this study was to determine whether menu design can influence the creation or modification of a user's conceptual model by exposure to an application, without explicit prior instruction. Relationship and sequence are the structural aspects of internal models considered most likely to be susceptible to incidental learning. Vocabulary alignment is expected to have an important doorkeeper function. Because there are few studies exploring this type of learning in complex workplace applications, the study also explores what conditions are likely to effect this process. This can further guide interface design for such products.

The three menu types reflect a range of alignment with the embedded model. The WIN menu acts as a type of control for comparison purposes. It is the oldest menu form in use and least reflects the model's task processes. It was therefore predicted to have the lowest structural alignment scores. It also includes a few, intentional, vocabulary inconsistencies so participants were expected to align with application vocabulary somewhat less than the other two treatments. The intermediate style of the WEB menu reflects both the structure and vocabulary of the underlying conceptual model and is a common, familiar design. The novel MAP menu was expected to provide the strongest support, combining visual and textual navigation aids and user-controlled supplementary information that provides additional scaffolding.

Summary of Findings

All groups showed improvement on alignment measures over time. Learning happened for almost everyone despite the perceived level of difficulty, the brief exposure time, and participants' statements that they learned nothing. However, interaction with the different menu types was not statistically significant under the experimental conditions present.

Quantitative measures of menu differences like number of clicks required,

number of menu items in a category, or actual visual complexity did not fully account for the level of difficulty experienced, even when domain or analytical experience was factored in. Similar studies (e.g., Tuovinen and Sweller, 1999, comparing exploration and worked examples) found that people with lower content expertise were more susceptible to treatment format and did better with defined tasks. That did not hold true in this study. Neither group explored more than the other, all were given specific tasks, and only the SEQ measure showed a treatment interaction.

Although research suggests that participants with related prior experience could have a conflicting mental model that would inhibit alignment, this covariate did not have a significant effect under the conditions of this study. Either no participant could be considered expert enough to matter or other factors weighed more heavily. If this influence is present, other factors are stronger and have masked any contribution. A second covariate, analytical experience (ANA), was suggested by results but these differences were also inconclusive.

There is substantial research that menu design has a strong effect on accurate and efficient use of online menus (insert REFS). Such usability measures do correlate with learning even if the outcome is development of an inaccurate or insufficient mental model of the tool. The treatments in this study reflect differing degrees of consistency and representation for each measure (Table 12). For instance, is the terminology used in the menu consistent with its use in page content? Does the grouping reflect model relationships? Does the format imply order? Stronger differences in navigation performance (time, number of clicks) should have been apparent even if effects for the dependent measures were too small for detection. Since effects were less evident, this is most likely due to unanticipated factors that either dilute or mask such effects.

Table 12. Match to Embedded Model by Menu Type and Measure

	WIN	WEB	MAP
VOC	Inconsistent	Consistent	Consistent - Enhanced
REL	Different	Same - Simplified	Same - Enhanced

SEQ	Not represented	Same - Simplified	Same - Enhanced
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The analysis does show consistent trends that are informative and worth further consideration, especially if obscuring conditions can be accounted for. Each measure is reviewed next to identify additional influences.

Vocabulary Alignment (VOC)

The VOC measure is assumed to be a prerequisite for structural alignment. If you can't interpret menu items, performance will be immediately impacted and learning slowed. All workplaces have vocabulary unique to their task domain and culture. Instructional Systems Development (ISD) is no exception; even educators cannot be assumed to be familiar with the vocabulary in this context. Despite being told to expect unfamiliar terms, complaints about the terminology were common and it appears that most participants had few strategies or little inclination to manage this. Comments suggest many felt as confused at the end as they were at the beginning. However, all groups show statistically significant time results on this measure. One can be expected to quickly pick up meaning for a few simple concepts when exposed in context. More importantly this also occurred in this study where there were a large number of unfamiliar concepts and some words were common but used in unfamiliar ways. The context which would normally help with interpretation was too unfamiliar to assist, there was interference from the perceived difficulty - and yet, there was a positive movement toward alignment in interpretation.

The preponderance of exposure to terms was through interaction with related page content (the same for all treatments), not menu items. This can account for the lack of menu interaction with the VOC measure. The WEB and MAP menu items presented terms slightly differently (MAP added verbs) but otherwise each used exactly the same terms as concepts found in page content. The WIN group had more discrepancies and performed slightly worse on the post-test as predicted. If the terms had been more inconsistent or frequently used a mix of synonyms as is common, it is almost certain that scores would have not improved as much as they did. Although

the additional explanatory phrases and use of verbs by the MAP menu offer greater precision in meaning, the shorter statements used in the WEB menu may have been preferred as "simpler".

Structural Alignment (REL and SEQ)

Participant feedback suggests that the MAP design which most strongly exposes the modeled structure was not the preferred design. This review of structural features suggests a tension between individual preferences, interface design guidelines, and approaches that research recommends for more durable learning.

Relationships provide the structural glue for connecting concepts in a usable pattern. Sequence orders these connections and can indicate size, conceptual nearness, and prerequisite steps. The navigation interface can act to organize pages into a structure that conceptually and visually represents the underlying model (but doesn't always). In this case, the model is based on the concepts and processes of traditional Instructional Systems Development (ISD).

The menu styles were designed to support learning in different ways. The MAP menu explicitly exposes relationship and sequence aspects. It visually augments the sense of relatedness with different visual styles for main menu groups. It leverages common spatial navigation knowledge and map-reading skills (i.e., identifying landmarks and roadways connecting different types of "neighborhoods"). This is in contrast to the simpler linearity of sequence implied by hierarchies used in the WEB format. The WEB menu is an intermediate approach that matches the embedded model but presents only a two-level, simple text list. The WIN menu uses the same concepts as the other types but these are grouped differently than the embedded conceptual model of the application. Items are sequenced alphabetically with no relation to process flow.

Although the order of menu items is the same for MAP and WEB, the perceptual impression is not the same. The list format of the WEB menu has little detail; it *looks* simpler. The landscape of the MAP is rich in both detail and navigation options implied by the many interconnecting paths. Progressive disclosure

techniques are used to reduce the amount of information seen at any one time but the visual nature of the format increases the information density substantially (i.e., "A picture is worth a thousand words"). This richness adds to the cognitive load.

One person commented that she found the MAP menu so visually inviting that she felt compelled to visit each building. This was a distraction that confused her and interfered with her focus on finding the target data since many pages were inactive (e.g., all of the Production pages). She said she later watched her son work with the WEB menu and thought the text-only items were much easier to ignore.

The circular path of MAP as a navigation device is also less familiar despite the assumption that clockwise movement is commonly used in diagrams to show sequence. The method did not carry over between contexts of use.

All menu groups increased in alignment within groups but despite these design differences, there was no significant treatment interaction for the REL measure. The WEB menu showed the greatest positive change in post-test scores and its SEQ measure came closest to a statistically significant interaction ($p=.07$, one-tailed).

This disagrees with the initial prediction that alignment would be greater for the MAP condition. This is likely due to the WEB's simpler but still ordered appearance and constantly visible nature, characteristics that the other two menu types lack (see Table 5). Most WIN users felt their menu was difficult to use. This was expected and is supported by the higher drop-out rate for WIN users.

Limitations

This study was designed to look at specific aspects of navigation design but was also intended to reveal other less well-defined elements that might have an impact. There is a concern that some predictions are no longer valid when applied in a more realistic context. Also, narrowly focused studies risk missing important environmental influences so a broader landscape was chosen for this study. This presents different impediments to conducting the study and greater ambiguity in interpreting results but offers stronger ecological validity.⁵² For example, accepting

⁵² See Glossary: *Authenticity*.

an unrestricted population which is exposed to the full complexity of a task-based application introduces a greater range of potential, interacting factors and requires more assumptions to be made where specific guidance is unclear. All can be sources of experimental weakness. This section explores those conditions that might clarify the trends present in the results.

Interaction of Navigation and Page Content

The navigation interface acts as a gateway to the pages, an organizational mechanism. The time spent navigating was minimal compared to the time spent searching and selecting target data. Since pages are the same for all treatments and the difficulty of selecting unfamiliar data increased times beyond what was anticipated, little difference could be expected.

A clearer separation would be needed to distinguish differences due to menu format. Navigation can only be artificially separated from the page content it is used to access. When both are presented together for maximum realism, alignment scores will contain contribution from both sources. The navigation should amplify any alignment contributed by the content pages. Since the representation of the underlying model differs only in the navigation interface, differences must be due to either the menu type and/or other unexplained factors.

Two conditions that interfered with the focus on navigation were the design of the tasks and the need for more explicit instruction. Results show that tasks required more time and thought to be spent setting up page content to display target data than was needed to select and go to pages. Given the presence of other mitigating factors discussed in this section, the augmenting effect of navigation was not observed with statistical significance. Measures like path analysis that could have better segregated the navigational aspects had to be set aside due to the explicit instructions. Future studies may find a balance between artificial segregation and full realism by reducing the perceived task complexity or by targeting a study population of domain experts to lower sources of cognitive load.

Alignment Scoring

Alignment scores were assumed to be randomly distributed on the pre-test. For most questions this was confirmed by a statistical test where each answer was assumed to have a random probability of a third. A few questions showed no movement in alignment scores between the pre- and post-tests but these were not excluded. Non-informative results were likely due to a ceiling effect of prior alignment or common knowledge that was unchanged by the study, especially for the vocabulary measure. Some of the vocabulary used, such as "Subtask", can be inferred from past experience, some can't, for example, "Effectivity".

Scores for each measure treated all questions equally; they were grouped together and a mean obtained. Analysis was not done to investigate the outcomes for individual aspects of each measure. For example, more detailed questions could have been asked about whether scores were different for questions about the relationships within Learning Analysis (LA) compared to Curriculum Planning (CP). For the LA main menu category there were several tasks and therefore more contact time; CP had a single task. This information may have been able to better clarify overall trends.

It was also assumed that the task part of the study would account for any changes in responses between the pre- and post-tests and that the cognitive load imposed by the intervening tasks would make it difficult to remember pre-test answers. Statistical results support this for the Time measure; there is little likelihood of primacy or recency effects.

Familiarity, Expectations, Low Effort Thinking

Emotions, social support, and motivation have long been linked to learning and can strongly hinder or facilitate cognition. While efforts were made to counteract these known effects, the perceived difficulty level and attendant emotional responses to it were highly underestimated. Although certainly some participants came briefly out of curiosity without intending to complete the study, about two thirds of those that finished found the tasks difficult and therefore stressful. Given the high attrition rate, it is safe to say this is a conservative percentage.

While an in-depth discussion of motivation is outside the scope of this study, it clearly drives how participants responded to stressors. It is an ongoing challenge in a self-directed online experiment like this study to provide motivation to continue when perceived difficulty is high. Four questions in particular highlight the issues that need more attention in this context.

(1) Did the participants' life experiences or personal preferences dispose them to a higher attentiveness to environmental details?

(2) How great was the person's tolerance for ambiguity: did they have strategies to deal with the unknown and complex?

(3) Was there social support present and of what nature?

(4) Would the issues be similar if using a more typical consumer-oriented type of software, for example, social networking, photo/video posting, etc., rather than a workplace type of application?

With one exception, there was no extrinsic source of motivation to offset negative feelings: participants were not paid, they didn't receive class credit or job recognition. Participants did not need to meet an externally-imposed standard of performance. There were no external negative consequences to quitting such as threat of job loss or loss of status. In this respect the study lacked personal consequences that are usually present when using such an application. This lack of external pressures primarily affected the attrition rate. The exception was one case where a participant arranged for a group of friends to take the study during one of their monthly get-togethers. Except to help each other set up and access the study, they participated independently. The social setting, however, had a positive effect on motivation and their sense of the difficulty level was lower.

The effect of intrinsic motivational factors is less predictable and difficult to counter. Despite frequent reminders that there was no correct path and that it was only necessary to try, not complete the tasks, most saw the study as a competence test. This attempt to mitigate stress conflicted with life experience that says performance *does* matter. The happy "You Found It!" message when a task was completed may have also been taken unconsciously as a contradiction.

It appeared that in some cases it was enough to have encouragement or a sense of competition. For others it was important to have another person available to direct attention to features like labels or control behaviors even when this information was also available in the application. These influences clearly affected outcomes and masked the differential effects of the treatment. They need to be investigated in more detail. Paas & Tuovinen, 2005, have proposed a computational approach to measuring student involvement that predicts the effort one is likely to invest during learning. It combines the effects of motivation as well as standard measures of mental effort and task performance. This may be useful in more targeted studies of incidental learning as well.

Based on the review of performance data and communications, three primary dynamics contributed to participants' perceptions of the study experience:

- lack of familiarity with the domain and with an application of this complexity,
- unrealistic expectations and diverging goals, and
- inattention and low-effort thinking.

Anxiety caused by stressful conditions such as these typically lead to three types of reactions: avoidance, blame shifting, and recasting. All three were strongly evident. When personal thresholds were exceeded, most quit. Others blamed design incompetence for their difficulties. Some revised their own goals and expectations to make continuation a more palatable choice. For example, several who spent a lot of time initially had not allowed themselves to look at the hints ("it felt like cheating"); they later chose to use the hints and significantly reduced their task times. These stresses were not accounted for. They are potent enough to dilute any underlying interaction and to be responsible for the high drop-out rate.

Familiarity

The sense of familiarity requires a sufficiently elaborate mental model to usefully predict a course of action. This informs expectations about the environment which includes the tool (application) and the task domain it is used for (in this case,

instructional development). Since it was expected that most would be unfamiliar with the domain, participants were encouraged to treat the task part of the study as a game where they need to find their way through an unfamiliar environment. Unguided exploration was assumed to be a common aspect of adventure games. Novelty in games primarily lies in the superficial details, not the underlying process. Games have predictable landscape elements, obstacles, and goals even though the visual presentation varies. This procedural predictability was lacking in WorkSpaces and few were able to accept it as a game. The interface elements were common but many still had difficulty with how to use them. If indeed they had prior experience with these controls in the applications they were familiar with, this skill did not transfer to a new application as much as expected. For example, there was confusion over using sequential dropdowns to select items from hierarchically arranged lists. Unfamiliarity with the terminology in use added to the perceived difficulty.

Expectations

Familiarity sets expectations. This appears to be an area where there was such a mismatch that it interfered with study progress. For example, most people only participate in online research through surveys. There were a number of people who completed both the Questionnaire and Pre-Test, then stopped. Comments suggest that they thought the surveys were the whole study. Their expectation overrode the description of the process provided in all solicitation materials.

Few seemed to have used workplace applications that created products more complex than a document. Despite a self-assessed, slightly above average sense of computer literacy, few participants seemed able to comprehend the breadth and depth of the application's functionality. They showed an unrealistic expectation of simplicity. No one said, "Wow, I didn't realize what all went into creating and managing good instructional materials before." Instead the refrain was that there were too many menu items, too many pages, the names of procedures were too long, there were too many choices in the dropdowns.

This is unrealistic and uninformed: the number of application pages is based

on the number of tasks required to produce and maintain materials.

Terms are mostly determined by company management and it is an economic necessity to use the same vocabulary as found in key resources like Maintenance Manuals. Interestingly, 90% of the data was removed to simplify use by the untrained participant; the remaining data was still considered too much.

The expectation of simplicity under all circumstances seems to be pervasive and culturally driven. Interface design has also adopted this mantra (e.g., the promotion of one-task one-screen, no context (Microsoft , 2001.⁵³ and others). In training, interface design, and many other areas, the KISS principle ("Keep It Simple, Stupid!") is foremost. It is often presumed that if learning requires effort, it is due to poor design, not the complexity of the subject. Outside of the classroom or in a job context, people seem to spend little direct effort on developing strategies for dealing with the uncertainty inherent in complex systems. Yet people will always find less familiar elements no matter how expert they become. If complexity is seen as a barrier, people will find the least effortful way to sidestep it. For many in this study, that path was avoidance.

Comments also indicated a presumption that if one is highly skilled in one area, such as art, this would naturally transfer to any other effort. There was little recognition that a novice user would have a natural lack of a rich conceptual model to support activities in a new domain. One participant complained that she didn't understand why this [study] was so difficult; she felt quite competent in all other aspects of her life.

Expectations and goals are interdependent. One woman noted that she didn't find the study difficult but she was used to being able to quickly see patterns in information. After completing four tasks, she was not able to do this and felt she had failed in an area she saw as her strength. She disliked the feeling so much that she quit despite other strong reasons to continue. She, like others, set a goal different from the study directions and judged success by a different standard. If asked directly, few would say that they felt competent in a new domain after a few contact

⁵³ Glossary: Inductive User Interface (IUI), KISS.

hours and no explicit instruction yet comments suggest this was a common expectation here.

Some participants accepted that the processes and vocabulary would be unfamiliar and set goals accordingly. This was typical of those that completed the study and had the lowest overall task times. Their comments suggest that a person's tolerance for ambiguity is correlated to the perceived level of difficulty. Comments like "I just followed directions, didn't worry that I didn't really understand – it was easy") doesn't mean that one isn't trying to understand. They accept that this understanding will take time and are able to continue to perform with less structure in place.

Attention and Cognitive Effort

Complexity imposes a cognitive load that is based on more than the application's features or individual skill levels; it is also a matter of user perception and expectation. The populations in each treatment group were very similar even when final group size varied due to uneven dropout rates. It could be argued that cognitive load should have been as similar as the population but it was not. Guidance for how to manage this burden is primarily directed to formal instructional settings, not this more indirect type of learning.

The higher the perceived difficulty, the fewer the cognitive processing resources available to meet task needs and the more performance suffers. In this study the ability to cope with abstract concepts and unfamiliar conditions was often reduced to concrete behaviors such as letter-by-letter matching of between instructions to application words and requiring the exact word order. Supports that could have helped reduce confusion such as information on how to operate the application were not used. For example, the Search function helps identify appropriate categories and terms to use in each context and can significantly reduce the amount of data to deal with. It was rarely used and may have been perceived as an extra burden. One could avoid learning to use this aid by using a smaller skill set and just scrolling despite the extra time and reading involved.

Help systems are an expensive function to incorporate. If they are not used,

the money and effort can't be justified. Help systems are hampered by user's reluctance to read instructions or help system statements longer than a sentence or two. However, oversimplification leads to misunderstandings that can inhibit task progress. It can encourage formation of models built on misperceptions that can be difficult to modify. There is much discussion on this topic but solutions tend to focus on ways to access the support materials available: what development tools are available, how to contextualize keywords searches, whether external .pdf's are better than embedded FAQs. These don't appear to address the causes of disuse since people are increasingly Googling their questions rather than using embedded help.

Both help systems and other resources require a mental model that suggests appropriate search terms since controlled vocabulary approaches seem to have become less popular. When successful, this type of support answers immediate issues of how the tool operates but does not necessarily help build a better model of the tool or domain of use. Without a more reliable model, frustration can interfere with the needed learning and users remain novices. In this study cognitive load appears to be a strong influence on the low use of aids. When stressed, the focus narrows visually and mentally. People are less likely to notice environmental cues such as a new dropdown box appearing below the just-selected dropdown, indicating that another selection is available at a lower hierarchical level. They may not see important supports at all and if they do, they may not recognize them as relevant. They may be unwilling to divert attention from their immediate goal or reluctant to invest more effort in a task of unknown difficulty. These hypotheses are advanced and elsewhere but clear answers are yet to be found.

The concept of perceived difficulty includes the emotion-bound components discussed earlier as well as cognitive effort. Low-effort thinking, as used in social cognition research, was encouraged during the pre- and post-tests. This technique is intended to more readily access existing perceptions by engaging in less effortful thought. By contrast, it was assumed that attentive processing would re-engage during the Find-It task part of the study. It did not initially; impaired performance and emotional responses led to substantial dropouts during the first task set. Participants

exhibited a poor level of attentiveness to instructions and page content during these initial tasks, commenting that items didn't exist when they did or that instructions were incorrect when they weren't. This is not surprising given the lack of a conceptual model that can assess which features need attention and which can be ignored.

When activity consequences are low, as they were perceived to be by most volunteers in this study, low-effort thinking is the norm. It is conservative by nature and its use is likely to increase under conditions of cognitive load and time pressure. This hinders the use of higher effort thinking like problem-solving. When cognitive processing resources are strained, the focus typically narrows, and the need to manage uncertainty increases. Participants may not have seen support features that could have helped, may not have recognized them as such if seen, or were unable to recall appropriate information. From this perspective the support provided by the constant visibility of the WEB menu increases in importance as does its more compact format. Likewise, several participants commented on how important the Copy Text button was since it keeps instructions visible that they otherwise easily forgot.

Feedback suggests that superficial scans of both menus and page content were more common than were careful, thorough searches. Two complementary explanations are proposed. This may be an unconscious effort to reduce cognitive load by attending to fewer features and is consistent with low-effort thinking characteristics. Participant comments suggest another cause: lack of experience with activities outside their own fields that require a high level of attention. Several expressed surprise at the level of precision required, that 'close was not good enough'.

In this study, for example, it is necessary to distinguish between items like "Perform Integrated WXR/Windshear System Functional Test" and "Perform Integrated WXR/Windshear System Operational Test". If the single word difference is overlooked, confusion happens. Since the terms for most target data were unfamiliar, participants also reported difficulty when the sequence of words in the instructions was not precisely the same as in the application. For example, Task

three instructions state:

"Make sure this System test has been added to the list of 767 Maintenance duties for Navigation System Procedures: Perform Integrated WXR/Windshear System Operational Test. "

To display the test information one has to select Maintenance duties/ Navigation System Procedures/System Tests in order from the dropdowns. Several noted that the tests were missing from the dropdown lists; when they saw "System Tests" in the third list, they expected to find it there. They didn't see this as another hierarchical category; they stopped looking. They didn't notice that the fourth dropdown (with the target tests) became visible to indicate the availability of another level of data as soon as the third level category was selected. Numerous such examples highlight the dependence on concrete attributes.

Novices in a domain are less efficient in processing information and have more limited attentional resources, particularly when encountering more abstract concepts. Where there is little guidance in determining feature salience, there is no anchor to attract attention. Although a number of common techniques for directing attention were used throughout WorkSpaces, (e.g., font size and weight, color, grouping, sequencing), this was not sufficient to overcome the anxiety of uncertainty and unfamiliarity; the perceived difficulty remained high for most. Design features were selected to reduce cognitive load for page tasks. Supporting information and functions were combined to reduce the need for users to split their attention between multiple sources of mutually referring information (Sweller & Chandler, 1991b). Redundancy was avoided to reduce unnecessary processing. Hints exposed a piece of the embedded conceptual model. Others like the Copy to Clipboard and more explicit instructions were added as a result of early trials and reduced memory requirements. These research-based techniques did help but were still insufficient to affect the perception of undue difficulty reported by the majority of participants.

Chapter 5

CONCLUSION

Use of complex, online workplace applications will continue to increase, especially as more organizations embrace cloud computing. The design of such productivity tools presents greater challenges; these tools require more user skills than those needed to maneuver through an information website. The terminology and tasks reflect common practice in the domain of use, for example, advertising management tools like DoubleClick reflect marketing methods and priorities, interdisciplinary tools like WorkSpaces delineate both a learning model and information management processes. These types of applications typically are intended to guide the user through integrated and diverse processes. Despite use by people of often widely varying backgrounds, consistent, predictable use is critical to task completion but the underlying conceptual model of the application is often not cohesive. This will make the application more difficult to learn and the user model may develop in ways that diverge from the intended one.

Research on the development of mental models suggests that conceptual relationships and sequence are key components. This study investigates whether these structural aspects can be learned incidentally when a complex application intentionally embeds a domain model. Secondly, it explores under what conditions that might happen. It is proposed that the application interface can do more than just support required tasks; it can also act collaboratively as an implicit teacher. Through exposure, the user 'learns by doing' and is encouraged to adopt a common understanding of the work tasks and goals. A shared model is critical to productive communication and quality of task performance.

The application ISD WorkSpaces provided the study environment. Three different menu types provided access to the same page content. As the doorway to content, these navigation interfaces have the potential to most clearly reflect tool and domain models. In this study they were hypothesized to differentially influence a user's schema of the task domain by moving it toward alignment with the model in the

software. A text approach (rather than the common, diagrammatic concept map) was used to elicit participants' prior understanding of structural aspects (REL and SEQ) and key vocabulary (VOC). This was compared to results after interacting with the application.

Hypotheses Reviewed

The study confirmed that interaction with the application led to learning and greater alignment with the embedded model (Hypothesis 1) even in the brief exposure time experienced. Since users will pick up substantive information this quickly, it is important that the message given by the user interface matches its goals. Too few usability tests check for this conformance.

The second hypothesis (H2) suggests that task performance is improved when using the more conforming models reflected in the WEB and MAP treatments vs. WIN. Trends and subjective measures reflect this position but this study was not able to statistically confirm this hypothesis. All treatments showed substantial improvement but there was little difference between menu types. This may be because the bulk of exposure time came from interaction with the same page content, not the different navigation interfaces. Still, other measures including subjective comments, task performance, and drop-out rates suggest that the WIN menu format is less capable of supporting development of an aligned conceptual model.

There was no significant effect of the prior instructional experience covariate (H2 and H4). 80% of participants had little instructional experience and therefore more impoverished conceptual models that would be unlikely to conflict. If an interaction existed for the remaining 20%, it was masked by other issues. The more analytical approach embodied in the WorkSpaces application may have appeared so foreign to the educators in the study as to eliminate the effect. It may be, in more realistic and complex settings, that a prior conceptual model will interfere less than expected or even support translation of unfamiliar elements to more familiar constructs. Certainly much of this lack of effect is related to the perceived difficulty level of tasks designed to ensure exposure to tested concepts.

Results for the third hypothesis (H3) agree with prior research on the efficacy of consistent vocabulary use. All participants showed significant movement toward alignment with the controlled vocabulary of the application. The primary exposure to terms was through page content, not the menus, so only a small difference could be expected. To better investigate this, it will be necessary to artificially separate the effects of navigation and content interfaces and perhaps introduce greater terminology differences. Although not statistically significant, the smaller inconsistencies of the WIN group did produce lower scores. Here again, issues of cognitive load are likely to have intervened.

The expectation that the MAP treatment would out-perform the other menu types (H5) was disproven under the conditions of this experiment. Although it most clearly exposed features of the embedded model, it also appeared to add significantly to cognitive load. There were a large number of abstract concepts present. Under these conditions inexperienced participants are dependent on more concrete concepts and could easily feel overwhelmed. The MAP menu was an unfamiliar format and is informationally dense despite techniques to reduce perceptual and cognitive demands. In this experiment as in an earlier investigation (Swanson, 2005), preferences were stronger for the simpler appearance of the WEB menu. However, the MAP format was preferred as a tool to explain issues during discussions.

Menu visibility was a key design difference between the WEB menu and the other treatments (H6). The WEB menu was the only treatment to show statistical significance for the SEQ measure. It uniquely provided a constant reminder of order as implied from normal reading direction of top to bottom. When perceived difficulty was controlled, the results for SEQ doubled in significance for WEB. The unfamiliar MAP fared more poorly on this measure despite the assumption that common use of clockwise order would transfer to interpretation of sequence.

Contributions

This dissertation proposes that the design of the navigation interface for productivity tools would benefit from a shift in the emphasis. Rather than the typical focus on a list of application features, an intentionally embedded, consistent

conceptual model offers a number of benefits. It can act as a focus for more coherent development. It provides a consistent, explicated basis for formal instruction and help systems. It can promote collaboration through common understandings of the work domain. ISD WorkSpaces is an example of this approach. The learning that happened was more than superficial, vocabulary converged despite the complexity and unfamiliarity of the content and lack of previous experience with this application and domain of use. It suggests that applications *can* act as implicit instructors.

The study also demonstrated that cognitive load and people's responses to this stress affected the success rates of study participants. The study achieved the complexity of real-world workplace tasks as was intended. It was able to show useful trends within a limited time-frame.

The study offers a framework for investigating structural aspects of conceptual model building under incidental and complex learning conditions rather than the usual, more controlled, formal instructional settings. It demonstrates a method of testing and scoring elicitation of incidental learning. It offers insights to better pursue more targeted experimentation when operating under such conditions.

An approach for online research was developed that allows people to participate independently at a time and location of their choosing. Data collection techniques were embedded in the application that made analysis more flexible and efficient. This experience clarifies challenges that need to be addressed in online studies of this type.

While the internet makes the study more widely available, it also presents challenges. Motivation to persevere is reduced without social supports and sufficient rewards. There are no external consequences for quitting or low effort so attentiveness is less controlled. Without a human monitor present, appropriate encouragement and re-directing attention are not possible; the target population is too broad to identify a narrow enough set of characteristics to predict individual differences that affect participation.

Support materials and help systems were embedded but they were only infrequently used in this experiment. They are expensive to develop and under

conditions of heavy cognitive load, people may not be able to use them.

The study highlighted the importance of consistency between the navigation and content page models. The WEB and MAP versions were consistent with the underlying model and performed similarly. When consistency was reduced, as it was in the WIN version, success was reduced and participants learned less. WIN negatively impacted the user experience; greater drop-out rates prevented learning. The study also confirmed the accepted importance of vocabulary consistency. It extended the applicability of this guideline to show that the need for consistency is even greater under the conditions of cognitive load found in more complex applications.

The study confirms the importance of simplicity when first learning to use an application but this also raises the issue of how far navigation styles like WEB can support increasing expertise. An offer to switch to a richer, alternative menu after becoming comfortable with one style is unlikely to be acceptable to most users. The more visual style of the MAP will undoubtedly become more common with time. If lack of familiarity was a strong factor, this impact should be reduced but does not address the general dislike of details requiring close attention. The navigation interface still appears best able to directly represent the underlying model but other avenues more focused on page content continue to be necessary. Menu research was very active in the early days of the digital age; it needs to be revisited under more modern conditions.

An important part of this study was to identify issues that future research could clarify. Those raised here include questions about how generalizable existing guidelines are and how these support more effective and durable thinking about the tool and domain of use. How much does the environment matter in terms of formal/incidental learning, social supports, as well as the content domain and application purpose?

Future Research

The level of cognitive load appears to be a decisive factor in participants'

experience: whether they continued and with what effort. Accepted research-based techniques were used to combat cognitive load; for example, controlling menu depth and breadth, using perceptual controls like color and grouping, supporting cognition by integrating tasks, providing multiple approaches to problem-solving, and making a variety of aids and support materials available.

A key question, initially assumed to be affirmative, is whether guidelines from explicit instruction and usability transfer between types of settings. The application was designed with close attention to issues known to cause cognitive load during learning and application use. While the design techniques used likely reduced the perceived difficulty, this study shows this was not enough to overcome the inherent complexity the environment presented to first-time users. Much of this research on cognitive load comes from formal instructional settings. In contrast this study relies only on the interface design to indirectly suggest the key structural aspects of a domain; it intentionally omits explicit instructional materials about the embedded model. Design techniques are derived from usability studies that do not generally consider the conceptual model being formed; usability definitions lack a strong focus on the characteristics of mental models derived from software interaction and don't ask whether that model matches the design. Usability also tends to lack a focus on more durable, higher level thinking. Under the conditions of this study, existing guidelines aren't as effective as expected. These may need adjustment to address what might differ under more incidental learning conditions but there is little research available to guide these changes.

It is generally assumed that as cognitive load increases, attentional resources become more limited. This may account for the lack of use of available support materials and inattention to embedded cues and perceptual aids found in this study. Design of productivity tools can benefit from a more detailed look at what accounts for this lack of use, under what conditions it occurs (which may differ in complex settings), and how to counter this effect from a design perspective. Potential questions include:

- do intended aids add to the informational burden,

- does lack of familiarity means that participants can't see them at all,
- are they able to recognize the relevance of available aids, or
- is trying once and failing enough to put off further attempts?

People want brevity and simplicity, answers in a sentence or two regardless of whether this is sufficient for the type of question being asked. Is this because it adds to the cognitive load? How much does this limit the richness of the mental models being built without conscious intention? Expertise was not a substantive issue in this study but is normally correlated to cognitive load. In this study all participants were application novices and few were more experienced in the content domain. Future studies that select and compare a general population with an appropriate, targeted one, for example, Instructional Design experts using ISD WorkSpaces, will need to address this issue. It is an ongoing challenge to design applications that can accommodate a range of expertise. The application must adequately scaffold a beginner's learning without unnecessarily cluttering the expert's work space or reducing expert performance. Ideally, the design also provides for continued growth beyond immediate, recognized needs in both operation of the software tool and an understanding of the domain for which the tool is created.

We all notice and productively incorporate environmental cues into our models of how the world operates - but generally no more than is perceived as useful in meeting immediate goals. To one degree or another we all resist change, the unfamiliar, the risk of perceived failure. In a rapidly changing and increasingly more complex world, we rely on digital tools to offset some of this burden. Technology offers options but also adds to the complexity. Two decades ago usability testing became an accepted process to guide technology into more human-compatible design. This field needs to find new ways of supporting human interaction that look beyond the application as just a tool. We are past the time where a simple tool like a shovel can be used 'intuitively'. Tools will need to collaborate, to participate more in the learning process. Current attempts to anticipate user needs have been less successful. A stronger focus on learning needs at a deeper, conceptual level seems to be more fruitful. This study is a step in that direction and proposes that we

leverage the type of incidental learning that we do every day, that we use technology as implicit instructors, not only as tools.

GLOSSARY

Domains such as psychology, educational psychology, information science, computer science, sociology, business, geography, linguistics, neuropsychology, neuroanatomy, and visual arts all do important research on areas relevant to this thesis. Each has a preferred vocabulary, idiosyncratic variations are created regularly, and substantial variation exists for shared terms. For me and, I suspect, others this creates a 'language barrier' for interdisciplinary research and a substantial memory burden.

This glossary defines key terms as I understand and use them in this dissertation and some alternates since it is expected that readers may have other interpretations. In particular, terminology for learning that takes places outside the classroom varies greatly. This thesis uses incidental learning to reflect the broad range of unplanned learning; it is not meant to imply any specific distinctions such as level of attentiveness, goals, social factors, etc. that characterize finer-grained assumptions of research in this area.

Other terms are included to reflect important concepts that informed this dissertation but were not explored in depth. These concepts may act as street signs, pointing to nearby neighborhoods of interest. For example, both geographic and conceptual navigation was explored to design the MAP treatment. Guidelines derived from different methods of explicit instruction informed the way participants' exposure to the application was designed. Analogy research explains much about novice thinking in unfamiliar settings.

The glossary also includes synonyms and related concepts to act as a brief thesaurus for the subjects in this dissertation since some are derived from disciplines other than cognitive and educational psychology.

Absolute navigation	Refers to the frame of reference employed during navigation, defined as coordinate system-based, environment-centered. This type of navigation typically uses the latitude-longitude system as in geographical maps.
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	See the contrast with Allocentric and Egocentric navigation frames of reference and Configural learning.
Accommodation	<p>A Piagetian concept describing a process where when new learning conflicts with an existing schema, it is changed to accommodate the new experience.</p> <p>See Cognitive dissonance , Schema and the partner concept of Assimilation.</p>
Action learning	<p>A type of 'learn-by-doing' strategy developed for the workplace, done in small groups. It stresses the importance of reflection on actions taken to initiate behavioral changes.</p> <p>See Revans (1982).</p>
Active learning	<p>A general term referring to the trend in the 1980's for shifting the instructional focus from teacher to the learner. Some theorists promote <u>behaviorally</u> 'active' participation of students; others see that this is disruptive in early learning stages and argue that a <u>cognitively</u> active participation is desirable (Mayer, 2004).</p> <p>See also Discovery learning.</p>
Activity theory	Proposes that activity is interdependent with the tools or artifacts produced by that activity and the way these tools are integrated into social practices. An extension of cognitive science theory, a paradigm influenced by Vygotsky to study human activity systems, which is beginning to influence HCI research.
Adaptive interface	<p>Also called personalized interfaces. One that changes based on prior user selections. For example, menu item location can be re-ordered to show most frequently used items first (adaptive split menus). Layered interfaces give the user a choice of interfaces to use to meet different task needs at different times or as the novice progresses towards expertise (Shneiderman, 2003).</p> <p>See also Interface agent, Intelligent user interfaces.</p>
ADDIE	Acronym for Analysis, Design, Development, Implement, Evaluate. A structured training methodology where each letter of the acronym stands for one of the 5 stages of the full training development process. It is used to analyze training needs, design and develop training materials, implement training, and evaluate its effectiveness.

	<p>WorkSpaces reflects an extension of this early approach to Instructional Design.</p>
<p>Allocentric navigation</p>	<p>Refers to the frame of reference employed during navigation: object locations are encoded in an external reference frame and defined as intrinsic, external loci, and object-centered. It is based on the use of distance and direction. It requires construction of a cognitive map. It explains latent or incidental learning and shortcut abilities. It is also considered a spatial updating model.</p> <p>Contrasts with Egocentric and Absolute navigation frames of reference.</p>
<p>Analogical reasoning</p>	<p>The ability to map a structure to isomorphs, and hence to make inferences based on the structure. It is a test for the presence of a representation of the structure. (Halford, 2007).</p> <p>Effective use of analogy requires little knowledge of the new target, but requires familiarity with the analogy source. The learner must be capable of analogous reasoning and recognize the boundaries of the analogy: where the similarities end.</p> <p>Analogy is a technique often employed in Information visualization. It maps one cognitive representation, the base, onto another cognitive representation, the target, on the basis of structural correspondence (Gentner, 1983; Holland, Holyoak, Nisbett, & Thagard, 1996). Unknown elements in one structure can be inferred by applying the mapping function to corresponding unmapped elements in the other structure.</p> <p>See Schema, Structure mapping, a theory of the structure of analogy, Association, Connectionist approaches to cognition.</p>
<p>Anchored instruction</p>	<p>A teaching approach that presents information using meaningful, problem-solving contexts, anchoring it to a relevant experience. Influenced by situated cognition frameworks. Introduced to overcome the problem of inert knowledge believed to stem, in part, from a lack of emphasis on 'when' and 'why' the knowledge should be applied. (CTVG, 1990; Crews et al., 1997). A form of experiential learning.</p> <p>See also Situated learning, Action learning, Cognitive apprenticeship, Problem-based learning.</p>

Artificial grammar	<p>The most common method employed in implicit memory and learning research to enable acquisition of a mental model to be measured with a minimum of prior knowledge activated. Uses meaningless series of letters, shapes, etc. which follow a set of rules which the subjects induce implicitly. Subjects' subsequent knowledge is tested to see if it is verbalizable and thus explicit or whether they can distinguish well-formed, grammatical sequences without awareness. Areas of reasoning, knowledge representation, learning, language have been most prevalent in research.</p>
Attention / Awareness	<p>Attention is the process of focusing mental resources on a stimuli, whether an internal idea or external object or event; of withdrawing from one stimulus to focus on another. The mechanism by which neurons are tuned to activate or inhibit signals. Characterized as either focal (under conscious, endogenous control; flexible, and selective) or automatic (reflexive; under unconscious, exogenous control based on salient perceptual stimuli from the environment such as size (landmarks) or movement).</p> <p>Focal attention is believed to integrate prior knowledge and current goals using 'executive' attention as a function that controls processing of incoming data. Eye movement metrics can be used when attention shifts are overt; covert attention may overlap but eye position remains fixed.</p> <p>Neuroimaging methods show that attentional modulation occurs rapidly within the visual system. When unattended (implicit) information is processed, it can influence the processing of attended information. For example, it can interfere or cause a reorientation of attention. (Posner & Digirolamo, 2000). The Stroop task is the classic example of attentional conflict between semantic and perceptual inputs, increasing cognitive load. Awareness is a prerequisite, relative concept. Perceptual inputs may be processed although the person may not recall being aware of a stimulus. Tests frequently rely on self-reports to determine awareness but can be unreliable because stimuli can continue to be perceived below the subjective threshold where observers are aware of the stimuli. Objective measures assess awareness based on perceptual discriminations; an inability to discriminate assumes lack of awareness.</p> <p>Perceptual encoding is assumed to be unconscious but may</p>

require attentional resources. Awareness may exist in an unconscious state since coma patients have reported memories of external stimuli, but in implicit research it is generally treated as the reception of conscious but unattended input, available to working memory for processing.

Merikle & Daneman (2000) distinguish between conscious and unconscious perception, the latter used as a synonym for awareness and equated with implicit memory. They describe how conscious and unconscious perception of the same stimulus can lead to qualitatively different consequences.

Both concepts are central criteria in implicit memory and learning for most researchers. Results from Curran & Keele (1993), for example, suggest that attentional and nonattentional learning operate independently, in parallel, do not share information, and represent sequential information in qualitatively different ways.

Findlater & McGrenere (2010) propose awareness as a low-cost tool for making design decisions and identify four related design factors: control, visibility, frequency, and granularity of the adaptation. For example, visibility can be hidden, moved, resized, replicated, and marked (e.g., color & highlights – see Tsandilas & Schraefel, 2005). They also caution that changes can have a negative impact on the user's awareness of the full set of available features, making future tasks more difficult.

Reed & Johnson (1997) point out that there is extensive evidence that focal-attentive processing can be dissociated from awareness, as with preattentive processes (perceptual encoding)

Dreisbach & Haider (2009) propose a 'global shielding mechanism' to supplement models of selective attention. This mechanism operates before interference occurs in contrast to current models which assume the mechanism is triggered after the fact. Their research found that when the task representation does not help to narrow the focus of attention, to help distinguish more salient features from less relevant, people are more vulnerable to processing more information than necessary.

See Cognitive Load Theory.

Authenticity	<p>A descriptor rating how close the learning context is to its real-world application rising out of the situated learning framework. Bransford et al. describe 2 levels: the first regards the objects and data, the second focuses on the type of tasks the learner is asked to perform. (CTVG, 1990). Used similarly in assessment approaches (e.g., Suen, 1997)</p> <p>See also Ecological validity.</p>
Automatic processing	<p>In contrast to controlled processing, Jacoby (1991) defines this function of working memory as a passive consequence of stimulation. It is not necessarily accompanied by awareness, and requires neither intention nor processing capacity. A process of implicit memory.</p> <p>See also Implicit learning.</p>
Blended learning	<p>A new term for an old concept. Refers broadly to an instructional approach that mixes different types of learning settings and delivery mechanisms, such as classroom lecture and stand-alone computer-based instruction or a mix of synchronous and asynchronous discussion sessions</p> <p>Related: Integrative, Hybrid, and Multi-method Learning. Reference Carman, 2002.</p>
Blending Theory	<p>A general theory of cognition also known as Conceptual Blending or Conceptual Integration, it is a pre-conscious process that combines elements of daily experiences to create or adjust schemas. Developed by Gilles Fauconnier and Mark Turner and influenced by Lakoff & Johnson's Conceptual Metaphor theory.</p> <p>See Analogy.</p>
Blocking	<p>People make judgments about uncertain future events or circumstances by calculating whether or not an outcome is likely to occur depending on the presence or absence of a cue. Blocking (lower expectations of a causal relationship) can occur when more than one cue has previously been associated with the outcome.</p> <p>Blocking is a key component of Human Contingency Learning.</p> <p>This often arises from inferential reasoning (Shanks, 2010).</p>
Breadcrumbs	<p>An online navigation aid, typically a line at the top of a website content area showing the path to the current</p>

location. It may allow navigation back to higher levels in the page hierarchy. It is used with deep or complex structures where it is intended to address the issues of lostness and disorientation. It is not often used in enterprise task-oriented applications.

In WorkSpaces this feature is only partially implemented. The WIN menu has none, the WEB menu keeps the current location visible and highlighted. The MAP version shows an icon (portion of the Map) on each content page.

Straub (2004): "Derived from Hansel and Gretel (Rogers & Chaparro, 2003), breadcrumb navigation provides users a persistent shortcut to find their way "home" on a Web site. Specifically, breadcrumbs are a secondary form of navigation (see figure below) that, in some cases, provide users the decision path they took to arrive at that page. In other cases, breadcrumbs reveal the hierarchical path showing the present page in relation to the information architecture of the site. (Users, by the way, tend to assume that the breadcrumb trail reflects the former, or their decision path.) She also states that users do not seem prepared to learn breadcrumb navigation on their own.

In a study of how much instruction it took to get users to learn to use breadcrumbs, Hull, Chaparro and Halcomb (2004) showed that the explicit instructions group used breadcrumbs to navigate approximately 1/3 more than other groups and resulted in faster task completion. Specifically, they argue that training makes sense in Intranet environments, where the ROI for the training would be more than offset by increased productivity.

Straub (2004) comments: "Still, the idea that users need to be trained should be a red flag. And the idea of providing training to public Web site users is not viable." [Prevalence of KISS principle.]

Martin (2006): "Breadcrumbs are designed to allow visitors to quickly navigate a site by providing a trail. Trails may be dynamically generated based on an actual path, which would vary from visitor to visitor; another option may be a trail indicating the site's prime architecture, regardless of the visitor's path throughout the site. The latter option, along with other navigation cues, may be better in helping site visitors form a mental model of the site (Rogers and Chaparro, 2003)."

	See also Interface objects.
Case-based learning	A more inductive approach to teaching where the context for learning is either real or hypothetical scenarios that require extensive analyses of a problem. Favored in medical education and related to the simpler scenario based tasks in this experiment.
Category learning	<p>Also known as concept learning. This study references this feature by the REL (Relationship) measure. A fundamental feature of cognition by which separate elements (physical objects, mental constructs, events) are treated as equivalent based on their attributes and form groups. Mervis & Rosch (1981) point out that categories are not arbitrary; counter to the classical view, attributes are combined into sets when the attributes are perceived as equally likely to occur.</p> <p>It is commonly accepted that basic level categories are acquired before categories at other hierarchical levels. Rosch et al. (1976) have shown that the basic level is the most general level at which (a) a person uses similar motor actions for interacting with category members, (b) category members have similar overall shapes, and (c) a mental image can reflect the entire category. They have shown that objects are recognized as members of basic level categories more rapidly than as members of categories at other levels.</p> <p>Learning involves distinguishing one from another through examples (e.g., Bruner, 1967; Medin, 1997; Chi, 1981; Estes, 1994) but theories diverge on the process, for example, identification of prototypes, perceptual features (surface similarities), progressive generalization, or probability assessment. Studies by Diaz & Ross, 2006; Lassaline & Murphy, 1996; Ross & Warren, 2002 provide examples of unsupervised learning of categories.</p> <p>Bassok & Medin (1997) found that semantic dependencies affected similarity judgments, that paired verbs had a different affect on interpretation than did nouns. This contradicts the prevailing structural-alignment approach to similarity which contends that there is a principled distinction between objects and their relationships.</p> <p>Murphy & Ross (2010) investigated these two sources of induction (features vs. category-level knowledge) by looking at whether people used information about correlated features within categories, suggesting that they focused on feature–</p>

	<p>feature relations rather than summary categorical information.</p> <p>Category-based induction generally ignores feature–feature relations and supports a more relational theory.</p> <p>See Relationship, Schema, Concept Map, Concept Learning, Classification.</p>
<p>Chunking</p>	<p>Units of meaning, for example, collections of related facts, that can be processed as a single item. A term developed from Miller (1956) that describes a memory strategy of grouping orthogonal bits of information into larger units (re-coding) with the result of extending the capacity of working memory.</p> <p>van der Veer & Felt (1988) suggest these are only expanded based on need.</p> <p>An important characteristic of expertise is the depth or richness of encoded chunks. The now-famous phrase "seven plus-or-minus two" refers to the number of discrete informational elements or 'chunks' that can be processed at a time. The richer the chunks are, the more information can be manipulated within this capacity limitation. An example is a beginner reader who attends to each letter versus a more experienced reader who scans whole sentences. The more expert a person is, the faster relevant information can be retrieved and the more likely it will be relevant to a problem awaiting solution.</p> <p>From a spreading activation perspective this mechanism also reflects the strength of associations between elements in long-term memory storage and provides an account of schema and prior knowledge on learning. In ACT-R code declarative knowledge is represented in chunks, a vector representations of individual properties accessed by a labeled slot.</p> <p>See Spreading activation, Context dependence, Expertise.</p>
<p>Classification</p>	<p>Categorization; a cognitive process; methods of grouping concepts at varying levels of detail, using open or closed vocabularies. Rule-based classification is an important form of explicit learning and may involve two types of associations: stimulus–to-category label and the reverse, label-to-stimulus.</p> <p>S. R. Ranganathan's faceted classification approach for library documents has influenced modern methods in many</p>

	<p>domains. Facets are different dimensions along (which objects can be classified, with each facet containing a number of terms.</p> <p>See Relationship, Schema, Meta-data, Controlled vocabularies, Taxonomy, Thesaurus, Ontology, and Topic Maps.</p>
Codified knowledge	<p>Defined as explicit knowledge. Closely related to public, propositional, descriptive, and declarative knowledge. Describes 'what' but not 'how' (see procedural knowledge). Eraut (2000) defines it as knowledge that is subject to quality control through discourse with others and has an accepted status through its use in formal education.</p>
Cognitive apprenticeship	<p>A learning theory based on the master-apprentice model, it emphasizes the importance of implicit knowledge gained through interactions and then making it explicit such that it can be applied intentionally. This theory proposes 3 stages: acquisition of declarative knowledge of a skill (cognitive stage), corrections of misconceptions and strengthening understanding of relationships (associative stage), and automatization of these processes (expert stage). Deductive teaching applies a similar process from simple to complex, reflecting the knowledge acquisition along the novice-expert continuum.</p> <p>This dissertation proposes that an appropriately designed application can take the role of master in a cognitive apprenticeship. The basic conceptual information is acquired through implicit modeling. It is preparatory for more explicit instruction where it can be made conscious and intentionally applied.</p> <p>See Situated learning.</p>
Cognitive architecture theories	<p>Theories of cognitive structure that attempt to define basic perceptual and cognitive functions of the mind using computational methods. These typically characterize the brain at a psychological level of description rather than neurological but overlap is emerging. Spreading activation theories reflect both levels.</p> <p>Ausubel (1968) proposed a theory that meaningful learning was due to the learner's existing cognitive structure. He later presented a hierarchical memory theory in which new concepts and their relationships are integrated hierarchically</p>

	<p>into existing cognitive structures.</p> <p>Another approach, now more common, is based on associative rather than hierarchical structures. Deese (1962) was among the first to use word association tests to assess such structures. These theories use word association, card sorting, graph building, and similarity ratings as assessment measures (e.g., Goldsmith, Johnson, & Acton, 1991).</p> <p>Theories of human information processing generally take a systems approach to model the interaction of human cognition and overall behavior. Examples include Soar (Newell & Laird), ACT-R (Anderson), both of which depend on sets of rules (production systems) and are implemented as artificial intelligence systems; Copycat (Hofstadter), and EPIC (Kieras & Meyer).</p> <p>Theories can be classified as either symbolic (not referencing a semantic layer) or connectionist approaches.</p> <p>See Expertise for differences in more or less expert structures. See Concept maps as an assessment technique. See also general structural terms of Schema, Mental Model, Conceptual Model, Cognitive Maps.</p>
Cognitive collage	<p>Tversky (1993) characterizes mental representations of environments as put together in an ad hoc way to suit current purposes rather than being retrieved as unitary wholes. She proposes that such mental representations are better characterized as cognitive collages than as cognitive maps.</p> <p>See Schema, Mental models, Cognitive Maps.</p>
Cognitive dissonance	<p>A well-accepted concept (see Festinger, 1957; Atherton, 2005) that describes the sense of disturbance or ego-threat caused when information or an experience conflicts with an existing schema or strongly-held belief. There is a preference for resolving this conflict, by ignoring it if possible, by denying the validity of the evidence, by rationalization/recasting (why it's not really in conflict), or by adjusting one's beliefs.</p> <p>Theories are less uniform in their specific attribution of cause and related processing mechanisms.</p> <p>See Schema and Accommodation.</p>
Cognitive Flexibility	<p>The theory of cognitive flexibility provides a framework for developing a case-based approach aimed at improving upper-level cognitive skills, particularly the ability to transfer</p>

	<p>knowledge to novel situations." (Graddy, 2001)</p>
<p>Cognitive informatics</p>	<p>The study of the cognitive structure, behavior, and interactions of both natural and artificial computational systems, and emphasizes both perceptual and information processing aspects of cognition (Chan, 2003).</p> <p>It recognizes both the task and context of performance. It involves processes of cognitive modeling and representation of human expertise in order to develop expert systems with a focus on their ontologies and knowledge bases. Chan quotes Card et al. (1983) who commented that "when psychology is applied in the context of a specific task, much of the activity hardly seems like psychology at all, but rather an analysis of the task itself".</p> <p>This is a relevant today as then. When task analysis is done from a conceptual model or schema perspective, the two should lead to similar or same results.</p>
<p>Cognitive load theory</p>	<p>Based on the premise of a limited working memory, cognitive load theory offers an explanation of "information overload" and assumes that information should be structured to reduce working memory load in order to facilitate schema acquisition. The premise is that reducing memory load can release cognitive resources to be applied to the learning goal. Instructional formats, the nature of tasks, as well as information quantity and complexity can impose processing loads.</p> <p>Cognitive load depends in part on the level of expertise in a domain as well as familiarity working with different types of materials. For example, Kalyuga et al. (1998) found that novices benefit from additional text (e.g., labeling) on diagrams whereas more expert learners have more developed schemas and do better with diagram only. Conditions of performance also have an effect. Task characteristics impact load differentially, for example, whether steps can be performed sequentially, whether elements interact and must be integrated (considered jointly, processed in parallel) to interpret, the level of segmentation (number of process steps), relational complexity (number of interacting variables), etc.</p> <p>The theory has been particularly applied to formal learning. Sweller 's theory proposes that instruction material be designed along these principles:</p>

	<ul style="list-style-type: none"> • Use goal-free problems or worked examples in problem solving tasks. • Present integrated sources of information to eliminate the need for students to split their attention between multiple sources of mutually referring information (Chandler & Sweller, 1991). • Reduce redundancy to reduce unnecessary processing. • Use both auditory and visual information where both are non-redundant to understanding. <p>A number of theories have been proposed to provide a metric for complexity effects: Relational complexity theory (which has a correspondence with Anderson’s ACT theories), the cognitive complexity and control (CCC) theory, capacity theory, MacLeod’s model of resource allocation, among others.</p> <p>Kieras and Polson's (1985) user complexity theory (later rephrased as cognitive complexity theory) have their roots in the basic principles of production systems and can be comprehended with the help of ends-means-selections and If-Then-rules, combined with the necessary declarative and procedural knowledge (Anderson, 1995; Newell & Simon, 1972).</p> <p>Bannert (2002) suggests that the CL research findings can extend to any complex artifact that we need to interact with, such as interfaces.</p> <p>Related term: information overload.</p> <p>See also Attention / Awareness.</p>
Cognitive maps	<p>Used loosely to describe both the output of representation tools as well as to discuss the structure of memory (cognitive model). As conceived by Patel (2008), these are “cartographic illustrations of a person's internal representation of the spatial environment in which they live”, helping to visualize position, location, and route information.</p> <p>See Cognitive Model, Cognitive collage, Concept map, Topic map, Schema, Knowledge structure.</p>
Cognitive Model	<p>A semantic space that is an organization or pattern of the internal representation of concepts and their interrelationships in long-term memory (e.g., Johnson, 1965; Preece, 1978a; Shavelson, 1974);</p>

	<p>The knowledge that the individual has and stores in long-term memory, and which includes facts, principles, formulas, and their organization, which might be incorrect as well as correct (Ausubel, Novak, & Hanesian, 1985; Greeno, 1983);</p> <p>A memory structure component, different from the perceptual component, which is composed of patterns of organization in long-term memory and of retrieval processes for concepts from long-term memory (Shavelson, 1974);</p> <p>A memory structure that is composed of epistemic and heuristic structures, which is distinguished from affective and behavioral structures and applies to all kinds of knowledge and not specifically to concepts (Schaefer, 1979).</p> <p>See Cognitive maps, Cognitive collage, Concept map, Topic map, Schema, Knowledge structure.</p>
Cognitive task analysis	A methodology for identifying and describing the goal structures that underlie observed task performance and to determine the relationships among specific task goals and subgoals. Related term: Cognitive work analysis.
Cognitive Toolboxes	<p>Cognitive Toolboxes (Mathews, 2001) involves analyzing course content into goal-based categories (toolboxes) linked to sets of knowledge facets (tools) and applications (cases).</p> <p>Memory of the knowledge facets (tools) was equivalent whether students developed their own organizational scheme or used the one provided by the course instructor (toolbox names) (Dunaway, 2001).</p>
Cognitive Transfer	<p>Most research been done with reference to transfer of cognitive skills and knowledge in the areas of problem-solving and analogical reasoning (Gentner & Gentner, 1983; Gick & Holyoak, 1980, 1983; Holland, Holyoak, Nisbett, & Thagard, 1986; Robertson, 2001).</p> <p>The study of analogy, computational metaphor, and the nature and quality of mental representations has been driving current research.</p>
Competency	As used by the ISBTP (International Board of Standards for Training, Performance and Instruction), it represents a related set of knowledge, skills and attitudes that enable a person to effectively perform the activities associated with a job or task (Spector, 2008).

Complex Learning	van Merriënboer and Kirschner define complex learning as involving "the integration of knowledge, skills and attitudes, the coordination of qualitatively different constituent skills and the transfer of what is learned in school or training to daily life and work settings" (2007).
Component Display Theory	CDT and CDT2 are Merrill's attempts to describe knowledge objects in way that would help a student to solve problems and in a parallel manner to a mental model. The later Descriptive Component Display Theory describes Merrill's explicit model of the components of the instructional process. Related: Elaboration Theory.
Computational approaches to cognition	An approach based on the belief that cognitive function is computational, that is, that the mind uses formal operations on symbols without reference to semantic content. Anderson's ACT-R is an example. The approach employs domain-specific symbolic sub-systems. Cf. Connectionist models of cognition.
Concept	A collection of ideas or things that share attributes, that are categorized together. Gagne and others distinguish between concrete physical objects: island, clothing, furniture) and abstract concepts (defined or constructed ideas with no physical counterpart). These 'chunks' help to make generalizations about category membership and the relationships between them. See Categorization.
Concept map (Cmap)	A diagram of memory schema; also a visual knowledge modeling tool. A two-dimensional, visually-based, node-link-node representation of the knowledge about concepts and their relationships within a domain, believed to accurately reflect internal schemas. Relationships can be labeled in any manner, for example, reflecting hierarchical or causal properties. The term conceptual or cognitive map is more typically used when referencing memory structure; knowledge map also occurs. Cf. also Tversky's (1993) Cognitive collage. Concept mapping is consistent with the theories of knowledge representation (Anderson, 1995), constructive learning (Duffy et al., 1991), and meaningful learning (Novak, 1990; Novak, 1991).

Many proponents assume knowledge is structured hierarchically, a characteristic adopted by most CMap formats along with static rather than dynamic relationships. Safayeni (2005) has proposed Cyclic Cmaps as an alternative for more information with more dynamic relationships. Related terms are spider map (node-link) and Venn diagram (overlapping groups).

Novak developed the idea in the early 1970s based on Ausubel's (1968) theory of learning development and an explicit constructivist epistemology. It became apparent to him that "meaningful learning was the most important factor in building powerful knowledge structures, and that these could be captured by concept maps." (Novak & Cañas, 2006, p.7). Leake (2004) points out that the Cmap doesn't just reflect internal knowledge, its structure also affects concept importance judgments.

Used in learning activities to take notes, show the relationship of concepts and topics for reports and oral presentations, or to act as scaffolding structures (e.g., Nesbit et al., 2006; Novak & Cañas, 2006; Rittershofer, 2005). Students constructed concept maps as a tool to 'teach' a software agent, Betty's Brain, domain concepts (Davis et al., 2003).

Tergan & Keller (2005) have extended common Cmap features to exploit its visualization capabilities but admit that it can pose high cognitive demands on the user. They classify features as structural, representational, processing, or usability features.

Research in concept maps has focused on their use in education as well as a representation tool for interdisciplinary relationships and business knowledge, to enhance negotiations and communication in collaborative contexts, elicit expert knowledge, to automatically generate or refine web queries (Leake, 2004), and in evaluation contexts to identify knowledge gaps, existing or changes to conceptual structure. Use as a navigation interface object exists only as a research tool or for limited, local exploration almost always accompanied by a more traditional navigation menu (e.g.

Concept mapping is a low-inference measure that requires lesser interpretation of the derived representations, even when an essay is transformed into a concept map format by the researcher (e.g., McKeown & Beck, 1990). (Hoz, 1997).

	See Knowledge Elicitation, Topic Maps, Mind Mapping Also 'fill-in concept map' and 'SAFI'; shared visual representations.
Concept proximity matrix	An quantifiable, computerized approach to scoring concept maps. Participants create the matrix by making a series of similarity and contrast judgments for each concept in the list. The matrix is subjected to a factor and cluster analysis to generate a spatial-dimensional and hierarchical cluster tree representation which gives global structural characteristics, for example, cognitive complexity, consistency, and taxonomic organization. See Aidman & Egan (1998) as an example of its use in the reconstruction of underlying cognitive maps.
Conceptual Model	Used in this dissertation as synonymous at a general level with Schema and Mental Model.
Conceptual visualization	Conceptual visualizations are intended to help learners develop understandings of a domain through dynamic visual representations that are based on cognitive research into the nature of cognitive frameworks or mental models (Jacobson, 2004).
Configural learning	As used by Thorndyke & Stasz (1980) it refers to the process of becoming familiar with a new environment. They proposed that this learning develops in three stages: spatial orientation occurs first by salient features, landmarks, in the environment. Route knowledge, the ability to move from place to place, develops using visual cues to make decisions. Configural learning is the third and final stage where the frame of reference is shifted from ego-centered (landmark and route) to a world-centered frame of reference. This knowledge of the structure of the environmental is represented cognitively in a form which Tolman in 1948 called 'cognitive maps'. See Allocentric, Egocentric and Absolute Navigation.
Connectionist models of cognition	Models that arose out of early work on Parallel distributed processing theories (PDP) and emphasizes the need for theories of cognition to take into account the physical, neurological level rather than only a psychology, descriptive level. The brain is characterized as a recurrent neural network that encompasses dynamical systems theory. Network states can be defined by the activation patterns of

	<p>its neural units (chunks) indicating connection strength. Learning is defined as a change over time in the relative weights of these patterns. Unlike computationalists, connectionists model semantic levels and severely limit the number of learning mechanisms posited. Neuroscience advances and the ability of this approach to incorporate computational approaches make this type of theory the current forerunner. Early proponents included James L. McClelland & David E. Rumelhart.</p> <p>Cf. Spreading activation, Hebbian learning, Computational approaches to cognition.</p>
<p>Consciousness</p>	<p>An overused word resisting an agreed upon definition. In implicit memory research it generally indicates the mental state of awareness. Conscious products are assumed to be the consequence of extensive unconscious processing and such products are processed differently than if they had not become conscious.</p> <p>Reed & Johnson (1997), in their discussion of whether learning requires consciousness, define learning as “acquiring an association that is at least of the complexity of the second-order conditional (SOC) learning” demonstrated earlier (p.263). ‘Requires’ implies that consciousness plays a causal role (strong interpretation) or that it sometimes plays a role and is only useful to distinguish between those processes accompanied by consciousness and those not (the weak interpretation). They view consciousness as a participant in a process.</p> <p>Merikle & Daneman (2000) distinguish conscious from unconscious states of perception, equating the latter with awareness. They state that there is little doubt now that unconscious (cf. implicit) processes “play an important role in determining feelings, thoughts, and actions” and that “qualitative differences that have been established show how conscious and unconscious perception differ” (p.1302). These differences indicate the strength of priming effects for information implicitly acquired and that these lead to automatic reactions. In contrast, interpretation of explicitly perceived information can adjusted as conditions change.</p> <p>In neuroscience, a more specific term, arousability, is discussed as a continuum between coma –drowsiness- wakefulness. See also Chalmers (2000) for a discussion of</p>

	<p>issues of neural foundations of fMRI research.</p> <p>See also Awareness.</p>
Construct	<p>Kelly (1955) used this term for the equivalent, schema.</p>
Constructivism	<p>A broadly accepted theory that argues that learning occurs when people actively interact with their environment, that they actively construct their own understandings, filtering it through idiosyncratic lenses of prior experience. It stresses the importance of multiple perspectives and context-rich, experience-based activities.</p> <p>This model is in contrast to the prior model, positivism, that learning is a passive reception of absolute knowledge. The variant, cognitive constructivism, is attributed to Piaget, social constructivism principally to Vygotsky. Derived instruction principles include using familiar, relevant content and experiences, encouraging reflection, and confronting misconceptions and contradictions.</p> <p>Often associated with ‘learn-by-doing’ teaching approaches. See for example, active learning, problem-based learning.</p> <p>The constructivist paradigm is characterized by how meaning is defined within the learning context. An Instructivist context is controlled by the teacher. Social constructivism says meaning-making is negotiated or shared and emphasizes the effect of the broader social context on an individual’s learning. Most approaches, such as situated theory, apprenticeship models, anchored learning and problem-based learning fall into this middle area. Radical constructivist proponents say meaning is defined only by the student; independent study is the appropriate venue for learning.</p> <p>Jonassen (1991, p.139) states “Rather than attempting to map the structure of an external reality onto learners, constructivists recommend that we help them to construct meaningful and conceptually functional representations of the external world.” In this thesis, while generally agreeing with this principle, I take a more moderate approach that assumes a consistent model is a benefit to less experienced learners when used not only as scaffold but as a predictable environment (in this case, an electronic task-based one) whose innate feedback provides a more robust foundation for extending the learner’s schema over time. That schema will necessarily diverge in detail, perhaps entirely, as the learner</p>

	<p>becomes an expert. However, many work situations do not support or desire innovation but rather consistent, error-free performance. This routinized behavior is as dependent on a useful schema as more adaptive expertise.</p> <p>See for example, Duffy, Lowyck, & Jonassen, 1991.</p>
Constructive memory framework (CMF)	<p>Proposed by Schacter (1998), this emphasizes the constructive nature of memory and focuses on encoding and retrieval processes. Encoding encompasses the initial binding of distributed features of an episode together as a coherent trace while ensuring sufficient pattern separation of similar episodes. Retrieval concerns the formation of an adequate retrieval description with which to query memory, post retrieval monitoring, and verification. The framework has been used in cognitive studies of young adults, neuropsychological investigations of brain-damaged patients, neuroimaging studies, and studies of cognitive aging.</p>
Content representation	<p>Covers a broad category of knowledge visualization devices ranging from local organizers, for example, headings, introductions and connectors, to global representations, for example, topic lists, outlines and concept maps. Text processing research has demonstrated that the principled use of content representations can facilitate the acquisition of knowledge from texts (e.g., Rouet , 2005).</p>
Context / Context dependence	<p>The perceived totality of circumstances in which an event occurs; the setting and the conditions and participants relevant to it.</p> <p>Godden and Baddeley (1975) confirmed the context-dependency of memory with their now-famous water-land experiment for recall of lists of words. They found that subsequent recall is better when the environment where the initial learning took place is replicated. Hewitt (1977) distinguished between intrinsic and extrinsic context. Intrinsic refers to perceptual features such as sound of voice or flower color that are encoded as part of the semantic context. Extrinsic context has to do with environmental factors like instructional setting. Hewitt found that only the intrinsic context showed recognition effects, in alignment with the Encoding Specificity Principle.</p> <p>In 1980 Godden and Baddeley replicated the Hewitt experiment and suggest that intrinsic context influences recognition and accounts of the differences between recall</p>

	<p>and recognition results.</p> <p>A more recent, related experiment by Crews (1997) finds that concepts acquired in a one context may not be readily perceived as analogous to a similar but different set of conditions, thus not retrieved or applied in other problem solving situations.</p> <p>Context dependence is a characteristic of expertise, that it is restricted to a specific domain (e.g., Ericsson, 2006).</p> <p>Macguire (2001) stresses the importance of context within usability activities, defining it as the goals of the user community and its main users, task attributes, and the environmental characteristics of the situation in which an application will be operated.</p> <p>See Contextual cueing , Encoding Specificity Principle</p>
Contextual cueing	<p>An implicit (automatic, without awareness) attentional or guidance effect that the environment has on memory and learning. Also called 'task valid cueing'.</p> <p>Cueing facilitates both recall and interpretation of available schemas during task performance and the construction of new schemas. (Hummel & Nadolski, 2002).</p> <p>Experts rely on contextual cues that activate appropriate schemas in problem solving (e.g., Ericsson, 2006).</p> <p>In their study of spatial invariance Chun & Jiang (1998) theorize that mental processes are implicitly sensitized to visually acquired, meaningful regularities in the environment such as spatial layout or landmarks. This allows faster perceptual processing whereas novel or changing elements degrade speed.</p> <p>See also Implicit learning, Navigation (aids, cueing).</p>
Control theory	<p>An engineering and mathematics theory that defines the how dynamic systems are influenced. It uses a specific notation for describing objects, states, and rules governing permissible actions that change the overall system over time. Related to Spreading activation theories where changes in state based on activation influence the behavior of connected units.</p>
Controlled vocabulary	<p>Using the same name for a concept consistently throughout a document, application, or other environment. Traditional</p>

	<p>taxonomic notation defines terms as either broader (BT), narrower (NT), or related (RT) and indicates scope (SN), what it is used for (UF), top term or highest element in the hierarchy (TT), and alternate terms (USE).</p> <p>Leise et al (2002) offer these definitions:</p> <p>“A controlled vocabulary is a way to insert an interpretive layer of semantics between the term entered by the user and the underlying database to better represent the original intention of the terms of the user...</p> <p>Organized lists of words and phrases, or notation systems, that are used to initially tag content, and then to find it through navigation or search</p> <p>A type of metadata that functions as a “subset of natural language”(Wellisch); it is not how we normally speak.</p> <p>A way to overtly display relationships among the various concepts... in order to increase findability.”</p> <p>They also believe that a controlled vocabulary promotes schema induction of the information structure explored.</p> <p>The term ‘vocabulary’ as used in this context is “a set of indexing terms, or subjects used for classification” (Garshol, 2004).</p> <p>See also Thesaurus, Glossary, Taxonomy, Ontology, and Meta-data.</p>
<p>Criterion Referenced Instruction</p>	<p>A set of methods developed by Mager (1984) in 1962 for the design and delivery of workplace training programs (see Instructional Systems Development). Like other ISD methods, it is based on the use of behavioral learning objectives. He emphasizes ‘needs assessment’ which consists of the analysis of performance gaps in terms of expectations, resources, and feedback, goals, and tasks. (See Task analysis). Particularly influential in the Performance Improvement field and management science.</p>
<p>Cyclic CMap</p>	<p>Safayeni (2005) proposed this extension to concept maps to distinguish between types of knowledge represented. He considers this type to be more appropriate for functional or dynamic relationships and complementary to the concept map (Cmap) which is best for static, hierarchical information. See also concept map.</p>

Declarative knowledge	<p>Knowledge of facts, ideas, events, and propositions. Awareness of some object such that it can be defined and described but does not imply that it can be productively applied to reasoning and problem-solving.</p> <p>It refers to knowing 'what' but not 'how' or 'why'. Usually distinguished from belief which does not require confirmation by external observation where results can be replicated. It is the type of knowledge generally referenced by epistemology, with a focus on the properties of a given entity. It is in contrast to Procedural knowledge.</p> <p>See Declarative memory. Contrast with Propositional knowledge, Procedural memory, Structural Knowledge.</p>
Declarative memory	<p>Memory for facts (semantic) and events (episodic). Often interchanged with declarative knowledge. Contrast with Procedural memory.</p> <p>In Anderson's ACT-R framework it is one of two memory modules, the other being procedural.</p>
Deductive Teaching	<p>A building-block approach that presents learning material in a sequence of cognitive effort, from simple to more complex generative knowledge and skills, for example, it first presents the name of the concept, then its rule or definition, then examples and non-examples. Generally preferred in workplace training settings.</p> <p>Prince (2006) describes the deductive method as typical of engineering and science where a general principle is presented, used to derive mathematical models and specific application examples presented and used to practice similar derivations. In this method the student is expected to absorb knowledge presented rather than construct their own understanding of it in contradiction of constructivist principles. He sees this as lacking perceived relevance on the part of learners, reducing motivation to learn in contrast to an inductive teaching approach.</p> <p>ISD WorkSpaces provides a systematic approach to development but places no restrictions on instructional strategies.</p>
Deliberative learning	<p>A term introduced by Eraut (2000) to describe one of 3 types of non-formal learning modes. It is explicit, intentional, and planned with learning as the desired outcome.</p>

Depth of processing	<p>A measure of cognitive effort that affects recall accuracy (Craik & Tulving, 1975). PET scans show higher brain activity for tasks that require deeper processing. The location of this activity is dependent on what kind of input is being processed.</p> <p>Low effort thinking focuses on more superficial aspects like orthographic patterns and is less durable, subject to forgetting. Deeper semantic processing, or higher effort thinking, leads to a more durable memory trace.</p> <p>Craik also states that recall is higher when environmental inputs are more familiar, when they match existing schema. Recall is also better when inputs are personally relevant or are perceived to include the learner in some way.</p> <p>Visual stimulus are believed to have the strongest recall value when they represent a concrete rather than abstract concept. Thus labeling of icons is recommended for all but the most familiar.</p> <p>See Durable Learning, Low effort thinking</p>
Design Knowledge	<p>Explicit or implicit knowledge of the how, when, and why a method or tool can be applied to a design problem. Experienced designers make use of recurring design patterns even if only implicitly. Explicit knowledge is captured in a large number of published guidelines that could drive development but more often do not because they conflict or are often either too general or too context-specific to be readily applied. See Design patterns as a method to emphasize the importance of context.</p>
Design patterns	<p>Encapsulated design knowledge of problem contexts and re-usable, previously successful solutions to interface challenges. Patterns are prescriptive and usually follow a template that specifies problem, context, solution, and forces standardization of presentation to facilitate comparison. Similar approaches have been used in architecture and software engineering. These do not explicitly reference research findings that support choices.</p> <p>See also Model-based User Interface Design</p>
Diagnostic teaching	<p>A teaching approach where lessons are designed to “discover what students think in relation to the problems on hand, discussing their misconceptions sensitively, and giving them situations to go on thinking about which will enable</p>

	<p>them to readjust their ideas (Bransford et al., 2000, p. 134).</p>
DIF Analysis	<p>A form of task analysis developed by the US military to evaluate the relative contribution of a task to overall job completion.</p> <p>In ISD WorkSpaces its primary purpose to help select task contexts to use as teaching scenarios. The overall criticality score is calculated from values of task Difficulty, Importance, and Frequency. To reduce subjective interpretation, the Importance criteria is subdivided into task requirements for Safety, Time Criticality, Situation Awareness, and Mission Criticality. DIF Analysis is only applied to Subtasks. These definitions apply:</p> <p>Difficulty: how much training is needed to learn this task;</p> <p>Importance: calculated based on values of:</p> <p>Safety: is a person likely to be injured doing this task,</p> <p>Time: how quickly must this task be executed,</p> <p>SA: how much attention need one pay to the environment while doing this job,</p> <p>Mission: what are the consequences of poor performance;</p> <p>Frequency: how often should a task be done to maintain skill.</p>
Discovery learning	<p>A more inductive, primarily self-directed method of learning. Teachers set problems and provide feedback and students discover course content for themselves. A variant, guided discovery with more teaching interaction is more often used to ensure learning objectives are met, leaving little distinction between inquiry-based or other inductive methods.</p>
Disorientation	<p>Often spoken of as the ‘lost in hyperspace’ problem, in navigation studies this refers to a degradation in performance due to a lack of a clear understanding of system relationships, its structure, rather than the user’s subjective feelings of lostness.</p> <p>Park & Kim (2000) state that disorientation is pressing problem in more unstructured spaces such as the Web and that disorientation occurs when users fail to realize the temporal-spatial context of their position in the space. The need to preserve this contextual information while navigating adds to the cognitive load or overhead. Structural context allows a person to decide destination options (forward</p>

	<p>navigation) while maintaining orientation. Temporal information shows the navigation path already traversed. Providing this as a Navigation aid can release cognitive resources for the task at hand.</p> <p>Dieberger & Tromp (1993) address this problem using a visualization of the content as houses presented textually in a MUD.</p> <p>Disorientation can be measured by revisitation metrics. Number of less relevant or irrelevant locations is a less reliable method in that individual curiosity and task focus are factors in open environments (those where choice are not constrained).</p>
Distributed cognition	<p>In psychology, a synergistic process in which cognitive resources are inevitably shared socially (collaboration) as a method to extend individual capabilities. Interaction may be asynchronous, co-located or not, and involve multiple input sources, for example, people, environments, tools such as computers. Extends situated cognition theory in terms of the interaction between people and technology.</p> <p>This dissertation ascribes to the corollary position that additional benefits are obtained when designing applications to be more than just a tool, to design them as more active participants in cognitive endeavors in a way that supplements rather than imitates.</p>
Domain	<p>A specific field of study, a specialized discipline, a set of interdependent activities that have an associated body of knowledge and processes.</p> <p>'Domain of use' refers to the area of endeavor that an application or other tool is designed to support. For example, curriculum management applications support Education, payroll processing applications are used in Human Resources Management.</p> <p>Also 'Focal Domain'.</p>
Drop-down box	<p>An interface object containing a list of items, used to select from a controlled set of permissible options for data entry or filtering search results. Filters can involve multiple drop-downs where each selection updates other choices. An example is the System-macro-component selection boxes in ISD WorkSpaces.</p>

Drop-down menu	<p>A navigation interface object used when space is limited where text-based main menu items are shown on a single horizontal line or vertical column. When clicked or hovered, a submenu is shown on a second line or column, depending on selected layout. A variation is the tabbed menu which operates the same way but appears as a (usually) horizontal set of tabs for either the main menu, submenu, or both. A more graphical variation is the current Windows ribbon with sets of icons arranged horizontally, used as a task bar rather than the primary menu bar. A cascading menu is a variation on the drop-down.</p>
Durable Learning	<p>Learning that lasts beyond the immediate need to use it such as for a test. It provides a firm foundation for future, deeper learning. Hacker and Niederhauser (2000) focus on instructional strategies like collaboration, opportunities for active knowledge construction, effective feedback, and motivation that can make learning durable.</p> <p>Knowlton (2001) uses Bloom's taxonomy to suggest that the lower levels of thinking do not qualify as durable.</p> <p>Contrast with Low Effort Thinking.</p>
Ecological interface design	<p>A theoretical framework for designing human-computer interfaces for complex and technical systems such as in aviation, industrial process control, and medical fields where centralized control of information is prized. See Vincente (2002). Uses a Skills, Rules, Knowledge (SRK) taxonomy to design training, emphasizing the role of skills and rules as a support for knowledge acquisition.</p>
Educational technology	<p>The study and practice of learning through the use of technology-based tools and resources. Can be synonymous with instructional technology but is often more encompassing. Spector (2008) characterizes the field as having 3 periods: the replacement era (the enthusiastic adoption of new technologies), the empirical era (testing when and why different features produced different outcomes), and the transformative era (how technology changes and transforms what people do). He argues that the field's greatest challenge now is to create the real-world, situated learning environments necessary to confront increasingly complex problems.</p> <p>See also Instructional Systems Development.</p>

Egocentric navigation	Refers to the frame of reference employed during navigation, defined as relative and observer-centered. It uses relative position of landmarks. See contrast with Allocentric and Absolute navigation frames of reference.
Encoding	A memory process that establishes and/or adjusts the contents of long-term memory traces (also called cognitive units) through the relative strength of associated neural patterns. See Spreading Activation.
Encoding Specificity Principle	A function of contextual cueing. Tulving during the late 60's and early 70's proposed that a retrieval cue will activate recognition or recall only if it is encoded with a learned item. Research focused primarily on semantics where context was needed to distinguish more than one possible meaning. See Context, Contextual Cueing.
Entity	In a database this term refers to a logical or physical object or set of objects. The object is able to perform an assigned task, can contain other entities, for example, teams contain people, and can be replicated. For example, a job task can contain subtasks that contain skills which can be assigned to lessons that are part of a curriculum. An item within that entity constitutes one independent physical object or piece of information. This approach is useful in describing components of mental models as well as workplace processes.
Entity Relationship Model	A software engineering approach to defining the conceptual model of a knowledge domain as embedded in an information system such as a database. The output of this effort is an entity-relationship (ER) diagram. Lindland et al. (1994) propose three kinds of quality criteria for models. Semantic quality refers to a valid correspondence to the real world. It is invalid if an object exists in the model but not in reality. Syntactic quality requires a valid correspondence of statements made about the conceptual model to its representation. It is invalid if statements about the conceptual model cannot exist in its representation. Pragmatic quality measures how accurately people understand the model. Teeuw & van den Berg (1997) propose generic, quality

	<p>criteria for all models: Completeness, Inherence (propriety), Clarity, Consistency, Orthogonality (modularity), and Generality.</p> <p>The conceptual model has the least technical data. It is used but not required to define the structural commonalities used in the logical data model. One or more physical models can be derived from the logical model. These are typically instantiated in a database as tables, indexes, and relationships.</p> <p>This model creates outputs similar to concept maps used in learning systems although practitioners in the two domains do not commonly communicate.</p>
Episodic recognition	<p>Dopkins et al (2010) define this as recognizing that an entity has been encountered before in a particular context. This is different from the effect of semantic priming in episodic recognition.</p> <p>See also Category learning.</p>
Epistemology	<p>The study of the nature of knowledge and its acquisition, typically of propositional knowledge and its attributes although there are proponents for including procedural knowledge as well. Ways of knowing. An area of disagreement is whether knowledge is a phenomena 'inside' the mind or 'outside.' Proponents of situated cognition have emphasized the external influences on knowledge and sense-making in contrast to rationalists. Constructivism focuses on the interaction between internal and external.</p>
Experiential learning	<p>A 'learn-by-doing' teaching approach. The process of making meaning from direct experience, by reflecting on one's activities, popularized by Kolb. Based on work by Dewey and Piaget. (Boud, Cohen, and Walker, 1993; Kolb, 1984).</p> <p>See also Action learning, Anchored instruction. Generally considered related to but not synonymous with informal and incidental learning,</p>
Expertise	<p>A measure of knowledge and skill acquired in a specific domain, typically viewed as a range from novice to expert. Expertise can be characterized by what dimensions are chunked and how large these chunks are (Sweller, 1988).</p> <p>Measurement approaches vary. Internal perspectives reference the sturdiness and richness of a person's</p>

	<p>conceptual models, external measures look at the quality of performance in terms of efficiency and accuracy.</p> <p>A study by de Jong & Ferguson-Hessler (1986) showed typical differences between more and less expert problem solvers when sorting a set of physics problems containing a scenario and both declarative and procedural knowledge. The more expert problem solvers sorted by problem category, the less expert by surface characteristics, reflecting both the extent of chunking and their cognitive structures.</p> <p>See Chunking, Spreading Activation.</p>
<p>Expertise reversal effect</p>	<p>Occurs when a learning procedure that is effective for novices becomes ineffective for more knowledgeable learners because processing redundant information might overload their working memory capacity (Kalyuga & Sweller, 2004).</p> <p>"When new information is presented to learners, it must be processed in a severely limited working memory. Learning reduces working memory limitations by enabling the use of schemas, stored in long-term memory, to process information more efficiently. Several instructional techniques have been designed to facilitate schema construction and automation by reducing working memory load. Recently, however, strong evidence has emerged that the effectiveness of these techniques depends very much on levels of learner expertise. Instructional techniques that are highly effective with inexperienced learners can lose their effectiveness and even have negative consequences when used with more experienced learners. We call this phenomenon the expertise reversal effect. In this article, we review the empirical literature on the interaction between instructional techniques and levels of learner experience that led to the identification of the expertise reversal effect."</p>
<p>Expert system</p>	<p>A restricted form of computer-based artificial intelligence that simulates the knowledge and analytical processes of one or more human experts. Typically references a knowledge base derived from elicitation and codification of subject matter experts (SMEs). Systems may or may not include an adaptive learning function. Inference rules use either a forward or backward chaining method. Forward chaining (or data-driven) starts with available data and chains forward until it finds an applicable rule. Backward chaining starts with the goal and looks for data associated with applicable rules.</p>

	<p>Expert systems encode problem-expertise on the data structures; the program remains generic. The system can be viewed from three perspectives: the knowledge structure of the SMEs, the knowledge engineer who represents elicited knowledge and defines inference rules to fill the data set, the end-user who is assisted by the problem-solving capabilities of the expert system, and the program that reflects the boundaries and nature of that capability.</p>
Explicit knowledge	<p>Knowledge that one is aware of having and can be verbalized. Temporary retrieval difficulties can occur, such as during test stress or due to age. Jacoby (1991) refers to the related processing as “controlled processing”, characterized by goals or intentions and subject to capacity limitations.</p> <p>Related to Intentional/explicit/formal learning and the inverse of Automatic processing</p>
Familiarity	<p>Familiarity implies an existing conceptual model that matches current stimuli. The familiar is experienced more favorably (Festinger, Schachter, & Back, 1950; Zajonc, 1968). Across several domains, perceivers simply assume that existing and long-standing states are good and desirable (Eidelman, Crandall, & Pattershall, 2009; Eidelman, Pattershall, & Crandall, 2010).</p> <p>This preference for the known can inhibit implementation of improvements that diverge too greatly from existing practice. The QWERTY keyboard is a well-known example that has not been superseded despite a layout that encourages misspelling.</p> <p>See for example, Analogy, Schema, Conceptual Model, Intuition.</p>
Fan effect	<p>An effect of computer models of memory that is conceptually similar but not functionally the same as neuronal activation. A psychological level of explanation rather than neurological description.</p> <p>This effect says that the activation spreading from a concept is divided among the concepts it spreads to. The ACT family of memory models explains the phenomena that the more declarative knowledge a person has about something, the longer it takes to respond to that topic (e.g., Anderson, 1983, 1995). However, experts have 'denser' chunking, thus fewer patterns to activate and retrieve faster than novices. The</p>

	<p>ACT models posit that each cognitive unit or chunk has an activation threshold associated with it and that retrieval time will be inversely proportional to that level. Additionally, activation spreads outward from that object to its neighbors, becoming more widespread – visualized as a fan. The farther the signal travels, the less it is able to activate its neighbors.</p> <p>Goetz & Walters, 2000). See Hopfield networks, Spreading activation.</p>
<p>Fill-in concept map</p>	<p>A scaffolded approach to creating concept maps used in many implicit studies because it requires only recognition rather than recall (e.g., Zittle, 2004). Uses a predetermined set of concepts. Aidman & Egan (1998) stress that both superficial and deeper classifications should be included and that the quality of the sets are critical.</p> <p>Also known as Fill-in-the-Structure (FITS) or ‘construct-on-scaffold’ (Chang, Sung, & Chen, 2001) where an incomplete concept map is provided with some nodes and links set as blanks for the scaffold.</p> <p>Schau et al. (2001), uses an alternate term: select-and-fill-in (SAFI), a method which assesses measures of internal consistency and relatedness. Mattern et al. (2001) confirmed that SAFI scores were strongly related to scores from multiple-choice (MC) achievement measures.</p> <p>Relational schema induction (Halford & Busby, 2007) also uses a partial completion paradigm.</p>
<p>Fitts' law</p>	<p>A model of skill acquisition that includes a cognitive phase (understanding the structure of an activity), an associative phase (practice until patterns emerge that expose the relationships and lead to automatization), and the autonomous phase where processing is more efficient due to elimination of attention on irrelevant factors.</p> <p>It is also considered a navigation model of untrained movement used in many settings, especially in electronic environments and HCI. It states the average time to move to a target is a function of the distance from the start point to the target center and the target width as measured along the route line of direction to the target. Results imply that any interface object requiring less travel and having a larger surface area will be easier to use. For example, top of screen menus are easier to use than top of individual windows because the latter require movement along 2 axes. (Zhao,</p>

	2002).
Focus + Context	<p>An information visualization technique used to navigate and manipulate/select items in large-scale online worlds. It provides the global context with an in-place zoom of a desired region of local focus to show more detail. Fisheye views, hyperbolic trees, and degree-of-interest trees are all focus + context techniques.</p> <p>It is based on the view that concepts, objects, and activities are best understood within their context of use.</p> <p>Pirolli, Card, & van der Wege (2001) find that these techniques can ease navigation and disorientation in complex environments by to preserving conceptual context , that is, increasing information scent based on the relevance of surrounding items.</p> <p>The MAP menu uses a variant of this technique to show more information when hovering over related areas.</p> <p>See Information Foraging, Information Scent, Fitt's Law.</p>
Formal learning	<p>Defined by Eraut (2000) as any learning situation having one of the following characteristics:</p> <ul style="list-style-type: none"> • a prescribed learning framework, • an organized learning event or package, • the presence of a designated teacher or trainer, • the award of a qualification or credit, • the external specification of outcomes. <p>See instructional methods such as Criterion Referenced Instruction, Anchored instruction , Discovery learning, Deductive Teaching, Cognitive apprenticeship, Problem-based learning, Case-based learning, among others.</p> <p>Contrast with Non-formal learning, Incidental learning, Implicit learning.</p>
Frame-based theories	<p>The term frame was used by Minsky (1975) to refer to schemas that contain knowledge about the structure of specific, familiar situations which induce expectations.</p> <p>See Conceptual model, Schema, Mental model.</p>
Frame of reference	Refers to the mode of navigation, classified by the spatial

	<p>focus or means of determining location and route: based on an internal map, based on observation of external features, or absolute – based on a coordinate system. The frame of reference employed affects flexible performance of navigational tasks.</p> <p>See Allocentric, Egocentric, and Absolute navigation.</p>
Generative learning	<p>Occurs when learners relate information meaningfully to prior knowledge, proposed by Wittrock in 1974.</p> <p>See Durable learning, Situated Cognition.</p>
Global vs. local navigation	<p>A guidance function of landmarks. Global landmarks define a world-centered reference frame that is constant. A local reference frame relies on a pattern of visible landmarks that changes as the observer moves. Local references can be viewed as "chains of intermediate goals and directions" (Steck & Mallot, 1998).</p> <p>See also Route navigation, Landmarks.</p>
GOMS model	<p>An explicit representation of expert user activity during task performance originally proposed by Card, Moran, and Newell (1983). A set of modeling techniques for Goals, Operators, Methods, and Selection. Selection rules are used to select Methods when several are applicable. The method employs a sequential set of Operators used to achieve Goals – what the user wants to do, the tasks. Can be used to predict task completion times. These can indicate interface impedances and, as a representation of user activity, provide a basis for help system design or explicit domain instruction. The model has had a significant influence on HCI and several variations have been proposed. Limitations are a lack of focus on any non-expert behaviors, individual differences, problem-solving behaviors, error sources, or qualitative influences such as user satisfaction.</p> <p>See also Learning objectives, Task Analysis, Design patterns.</p>
Graphical representations (GRs)	<p>Graphical representations include diagrams, maps, plans, animations, and virtual reality entities. They are distinct from text and formal notations such as logic or mathematics (See Larkin and Simon, 1987). Their use is often to convey "whole processes and structures, often at great levels of complexity" (Winn 1993). Research into the use of GRs generally has shown cognitive benefits over other formats, such as text, in</p>

	representing such types of information (e.g., Scaife, 2000).
Hebbian learning	<p>A type of associative learning arising out of Hebb's 1949 theory describing the connectivity of brain cells. Proximate cells that are activated at the same time repeatedly will tend to co-activate even when only one is stimulated. A mathematical method has been applied to learning, using weights to describe how learning elements are related so they can be adjusted appropriately.</p> <p>Using a model based on Hebbian learning, Stark & McClelland (2000) instantiate a property that they believe is characteristic of implicit memory: that learning is primarily based on the strengthening of connections between units that become active during the processing of a stimulus. They argue that this model provides a more satisfactory account of the data than does the error-driven model.</p>
Human-computer interaction	<p>The study and application of the programming layer exposed to the user. A research domain that now constitutes the central element of interaction design and is greatly influenced by information processing accounts of cognition. The preferred term in applied settings is now "user experience" design. Kutti (1995) has suggested that more frequently HCI follows practice, trying to determine why existing techniques work rather than providing leadership, a trend that has changed little.</p> <p>See User experience, Usability</p>
Implicit learning	<p>A form of relatively unconscious, automatic pattern-matching and association. Also, a by-product of interaction with a situation where the goal is to accomplish a task. Goal pursuit has been traditionally assumed to be strongly related to consciousness but is now, along with attention, considered to be a factor in implicit learning as well. An adaptation process through which the behavior of an individual becomes sensitive to a structure in an incidental manner and without the individual being able to verbally report or even consciously access the resulting knowledge (Reber, 1989). According to Schacter (1996, p. 172) "implicit memory, by definition, does not involve recollection of source information" and is prone to distortion and error.</p> <p>Considered essential for learning the sequential structure of language, plays a role in motivation and affective responses. An open issue is the extent to which this type of learning can</p>

	<p>be distinguished from explicit learning.</p> <p>Commonly measured in terms of perceptual “fluency”, subjective familiarity, objective measures of similarity (including fragment frequency and repetition structure, e.g., Scott & Dienes, 2008), grammaticality judgments (is it a ‘legal’ exemplar), structural knowledge (why it is ‘legal’ in terms of items and their relationships). Scott & Dienes (2010), however, find perceptual fluency a “dumb heuristic” that influences responses only in the absence of actual implicit knowledge.</p> <p>Fu, Fu, & Dienes (2007) found that task difficulty and the amount of training affected the expression of unconscious knowledge.</p> <p>Eraut (2000) uses this term to describe 1 of 3 types of non-formal learning modes.</p> <p>In this study this concept is used as equivalent to incidental learning since many characteristics are shared and there is no commonly accepted definition for either term.</p> <p>See Schacter (1987) for historical foundations of implicit research.</p> <p>Related: Incidental Learning, Unsupervised learning, Latent Learning, Structural Knowledge.</p>
<p>Implicit-explicit distinction</p>	<p>Traditionally considered distinct, dichotomous conditions.</p> <p>Mandler (2005) has stated that the unconscious and conscious are discrete memory states, but presents the concept ‘preconscious’ as a transitional representation that can reflect both full and partial states of activation.</p> <p>Ritter (2009) also discusses the blurring of these distinctions, introducing eight overlapping processing modes across these two intersecting dimensions. His results suggest that (1) systematic associations between implicit procedural and implicit verbal processes do exist on a microanalytic, moment-to-moment basis; (2) enhanced language style is related to higher degrees of switching pause autocorrelation and more midrange degrees of switching pause cross-correlation; and (3) there are implicit differences in speakers’ roles.</p> <p>In this thesis, as applied to learning, these two states are less discrete; they are viewed as two ends of a continuum that</p>

	<p>overlays the more distinct neuroanatomical substrates. The center of the continuum is a combination of both types, dependent on an individual's personal characteristics, the goal arising out of task interaction, and is variable. There is growing evidence to support such a perspective, that both can operate in parallel (e.g., Curran & Keele, 1993; Willingham & Goedert-Eschmann, 1999). Purely implicit learning may exist only in persons with specific brain impairments such as amnesia and Alzheimers. (Bowers & Schacter, 1993; Cermak, 1993; Shimamura, 1993).</p>
<p>Implicit Sequence Learning</p>	<p>It has been suggested that the weakness in implicit learning observed in dyslexic individuals may be related to sequential processing and implicit sequence learning. (Folia et al, 2008)</p>
<p>Incidental learning</p>	<p>Ubiquitous and spontaneous learning through unplanned interaction. An alternate but not synonymous term for informal learning, reflecting the intent of the learning rather than the setting. Also frequently used as a synonym for implicit learning which shares its lack of intentional learning.</p> <p>Marsick and Watkins (2001) define this by its contrast to formal learning with its highly structured, controlled learning. They also distinguish incidental from informal learning: "Incidental learning is defined as a byproduct of some other activity, such as task accomplishment, interpersonal interaction, sensing the organizational culture, trial-and-error experimentation, or even formal learning. Informal learning can be deliberately encouraged by an organization or it can take place despite an environment not highly conducive to learning. Incidental learning, on the other hand, almost always takes place although people are not always conscious of it (Marsick and Watkins, 1990, p. 12). It is generally believed that reflection is not required for behavioral change and has as its goal task accomplishment.</p> <p>Antony & Santhana's (2007) research on knowledge-based systems (KBS) suggests that though a KBS is primarily developed to help users in their decision-making activities, as an unintentional consequence, it may induce them to implicitly learn more about a problem. Results supported implicit learning through interaction with the information-based program. This is posited to also apply to task-based applications.</p> <p>Age-related implicit learning deficits increase with sequence complexity, suggesting there might be limits to the level of</p>

	<p>structure that older adults can learn implicitly.</p> <p><i>Related:</i> Unsupervised Learning, Implicit Learning, Latent Learning.</p>
Inductive teaching	<p>On a continuum between top-down/big-to-small vs. bottom-up/simple-to-complex teaching, this approach emphasizes the former. It first presents a problem to solve or a study to analyze that generates a need for facts, critical attributes, rules, or guiding principles. Resources are made available either through presentation or discovery methods. This is less common in workplace training where conformity and efficiency are preferred.</p> <p>See also Inquiry-based learning, Discovery learning, Case- or Project-based learning.</p>
Inert knowledge	<p>Stored information that cannot reliably be retrieved in relevant situations.</p> <p>A problem emphasized by Whitehead already in 1929, Bransford et al. define it as “Knowledge that can usually be recalled when people are explicitly asked to do so but is not used spontaneously in problem solving even though it is relevant” (CTVG, 1990). See also Crews et al. (1997)</p> <p>See Retrieval, Durable Learning.</p>
Inductive User Interface (IUI)	<p>The IUI is a user interface model proposed by Microsoft (2001) and implemented in Money 2000 that suggests that software applications can be made simpler by breaking features into screens or pages that are easy to explain and understand, that is, a single task per page with its purpose clearly stated in the page's title. The task context within the larger process is not provided despite their belief that many UI difficulties arise from inability of the user to form a clear mental model of the task as implemented in the software. They urge designers to “to value clarity and simplicity.”</p>
Informal learning	<p>Emphasizes the setting; any non-formal learning, learning that is unscheduled, impromptu, and takes place outside of a formal (intentional and organized) context for learning or self-initiated learning using formally constructed curriculum materials. Can include observation, asking colleagues questions or simple conversations, trial-and-error exploration, calling a help desk, working with a mentor or coach, reading blogs and wikis.</p>

	<p>Describes the bulk of human learning. Also called emergent learning, one that arises out of an immediate need as a result of environmental interaction. Often emphasizes the role of visual stimuli or feedback in this context. Cross (2008) argues that formal learning has been mostly ineffective and that the focus needs to shift to informal learning: 'natural', situated and relevant learning, especially in the workplace.</p> <p>An assumption of this thesis is that the interface itself can act as a colleague, providing an equivalent informal environment. Such a view blurs the distinction between planned formal learning by design and informal, environmental learning accessed implicitly. The navigation interface can be an important facet as a representation of the structure and relationships within the work environment. An important direction for future investigation will be how electronic tools can better take on the role of collaborative colleague rather than intrusive experts offering unsolicited advice as in the past, for example, Microsoft's Bob.</p> <p>Cf. 'non-formal' learning as defined by Eraut (2000).</p>
Information architecture	<p>The structuring or modeling of detailed information in complex environments; applying design and architectural principles to information; conceptual and logical categorization of information into a coherent structure. Focus on entities, attributes, and relationships. An applied example is a database entity diagram. Primarily a computer science term but also used in information science and other domains with somewhat differing definitions.</p> <p>See also Schema, Classification, Concept learning.</p>
Information Foraging Theory	<p>"Information Foraging Theory is an approach to understanding how strategies and technologies for information seeking, gathering, and consumption are adapted to the flux of information in the environment. The theory assumes that people, when possible, will modify their strategies or the structure of the environment to maximize their rate of gaining valuable information. Field studies inform the theory by illustrating that people do freely structure their environments and their strategies to yield higher gains in information foraging" (Pirolli & Card, 1999).</p>

Information scent	<p>A semantic clue that helps find target information more easily. A concept which assesses the value of information found based on nearby cues in information-rich environments. Such cues, for example, text summaries, are used to decide whether to continue to navigate towards more distant information sources or to change paths.</p> <p>Most commonly applied in a large or complex online environment, particularly in web information spaces (e.g., Pirolli & Card, 1999) like search results in Google but the concept applies equally to searches within physical/geographic systems. Here cues might be the height of buildings and signposts which indicate whether you are approaching a city.</p> <p>Budiu & Pirolli (2007) point out that most web navigation research overlooks how information scent and visual organization interact with each other and offers a model that takes both into account. Their ACT-R model measures two types of information scent, category and similarity. Scent is activated by the visual prominence and semantic applicability of a menu item or node. The higher the activation, the more easily it can be retrieved from memory.</p> <p>Other terms used for clues that lead to relevant information are navigational residue, scent, trace, hints, and cues (Jul & Furnas, 1997). These are considered essential in unfamiliar environments but infrequently considered outside of information searches. The traditional windows drop-down menus can be considered an example of a menu approach that lacks scent. The MAP version in this study incorporated a number of cues to aid navigation.</p> <p>An element in Information Foraging Theory. See also Navigation, Navigation Aids.</p>
Information spatiality	<p>Uttal et al (2006) uses this term to describe the quality of space that information can impart, much the same way the physical environment does. People acquire spatial information from many sources, including maps, verbal descriptions, and navigating in the environment. The different sources present spatial information in different ways that can influence schema induction. For example, maps can show many spatial relations simultaneously, but in a description, each spatial relation must be presented sequentially.</p>
Information	<p>The study and practice of accurately representing large,</p>

<p>visualization</p>	<p>complex data sets and information repositories using spatial and graphical techniques designed specifically to take advantage of human perceptual and cognitive characteristics for the purpose of communication. A technique for making abstract information more concrete to aid comprehension. Key criteria are scalability and usability – and of current interest, the ability for the user to tailor the visualization to meet specific needs.</p> <p>As an approach to knowledge discovery, goals go beyond improved interpretation of complex data; they touch on issues of creativity and discovery (e.g., Ramadas, 2009 who emphasizes the uses of imagery for schema formation and conceptual change in the sciences). A visualization should not only provide structured access but also expose relations within content regions while representing the entire phenomena (e.g., Gordin & Pea ,1995).</p> <p>2D techniques manipulate color, size, position, and semantic symbols. Wiss & Carr offer a framework for 3D visualizations where the additional criteria includes consideration of attention, level of abstraction, and affordances – criteria that are applicable but often not considered in 2D representations. Rekimoto & Green (1993) point out that because of the large size and complexity of the information, 2D techniques may be inadequate. They propose a 3D-based techniques or semi-transparency of nested levels as a means to increase scope.</p> <p>Other techniques for visualizing and exploring data include structuring, filtering, cuing, and dynamic adjustments and are influenced by the type of data. Hierarchical data techniques include fish-eye views, tree maps, beam and cone trees. Hypervariate data is often represented by types of scatter, star, and parallel coordinate plots. Distortion and animation techniques can be applied to timelines and event streams, zoom & pan to landscapes, and semantic zoom to whole-part object displays.</p> <p>In research with designers, Tversky (2005) contends that imagery may be a component of procedural memory and views visualizations as a form of applied spatial cognition. Madan et al. (2010), using probabilistic model fits to data, suggests that imageability primarily improved retrieval of associations, but frequency primarily improved recall of target items.</p>
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	<p>Used in human computer interaction, digital libraries, query formation, display of retrieval results (e.g., Hoeber, 2009), science, data mining, graphic arts, finance, among many others. In education the research has focused primarily on communication properties of pictures and diagrams rather than mental imagery produced. North (2000) contends that the multiple visualizations combined in interfaces are highly dependent on the data, tasks, and users. He presents brushing and linking, overview and detail, and drill down as valid coordination techniques.</p> <p>There is a movement toward visual over text lists based on user preference and efficiency of use, for example, using a map approach for search results. Don Clark (e.g., 2007) uses a concept map-based image as a navigation device.</p>
<p>Inquiry-based learning</p>	<p>Also called guided inquiry. A more inductive teaching method using a problem-solving approach. Learners are set a challenge such as a question to be answered, an observation or data set to be interpreted, or a hypothesis to be tested.</p>
<p>Instructional Design (ID) Theory</p>	<p>Reigeluth (1999) defines an instructional design theory as one that offers explicit guidance on how to better help people learn and develop via choice of information, opportunities to practice, thorough feedback, and motivating conditions. It is focused on design and practical application unlike, for example, theories of memory. Most ID theories are systematic and prescriptive; they present quite detailed methods and assume these improve the chances of learning but do not guarantee it. Gagne (1988) proposed that an instructional theory assumes there are different kinds of learning goals or outcomes and that these require different approaches to accommodate different conditions. He presented nine events of instruction to consider in design. His work has influenced ISD and is still the basis for most military training.</p>
<p>Instructional Systems Design/Development (ISD)</p>	<p>A systematic method applied to the design and development of instructional materials, from lecture notes to 3D simulation environments with an instructional intent. The 'D' in the acronym is ascribed to 'Development' primarily, but is also interpreted as 'Design'. Jul (2004) characterizes design as a problem-solving and decision-making iterative process with 3 phases: generation, realization, and evaluation. This description applies well to ISD processes but with less detail.</p>

	Initially designed for deductive, deterministic teaching approaches and most commonly applied to such, the method does not innately require a form of instruction other than to stress a systematic process with clearly stated objectives which will reflect the teaching method. Different frameworks arise out of instructional theories that all share a notion that materials should be designed in accord with learning goals and psychological processes but different in the interpretation and emphasis, the vocabulary, and the classification of elements.
Instructional Transaction Theory (ITT)	An algorithmic model of instruction based on manipulating knowledge as data. Specifically designed to facilitate the design of computer-based instruction. (See Reigeluth, 1999).
Intelligent user interfaces	Those interfaces that embed models of the user, domain, task, and other features to improve the naturalness of the interaction, thereby improving efficiency and accuracy of performance. (See Shneiderman & Maes, 1997). Such interfaces use an agent to mediate communication between the software and user, such as the animated agents in Betty's Brain (Davis et al., 2003) or Microsoft's 'Clippy' and 'Bob' functions. Agents may also be no more than the functional parts of the software evaluating user actions and predicting likely needs or future actions and then adapting the interface to support these predictions.
Interface agent	A software functionality used in personalization and as a cognitive support. Models, based on data continuously collected to build user profiles, identify how and when to interrupt and support user preferences and needs without disrupting task performance. See also Intelligent User Interfaces.
Interface objects	Interface objects are the communication tools in an interface that mediate and translate user actions or commands to the machine. They can be categorized as navigation, data entry, selection, or guidance features, in addition to application-specific commands. Navigation objects include menus (global) and command buttons (local) to open a specific window or page. Other objects may have a navigation function built into the code executed as a result of a predetermined user action but not directly accessible to the user. See Navigation interface.

	<p>Text boxes are the most common data entry field and allow free-form text entry, and may have input prompts or type-ahead features. Static text boxes present data for display only.</p> <p>Selection objects are used to indicate a user preference, select a specific data set, control data entry, or to filter extensive results. They can be contiguous (in the same grouping) or disjoint (spatially or logically separate). These are common selection objects:</p> <p>Check box to select items from a short list,</p> <p>Combo boxes combine a text box and drop-down list box. Items can be selected from the list (controlled) or optionally, by typing new options directly (uncontrolled).</p> <p>List boxes are most often single selection with all items displayed or using a drop-down box which expands to allow selection, then closes to show only the selected value. Extended and multiple selection list boxes are alternatives.</p> <p>Radio button sets select a single item from a short list. Selection of one item unselects all others.</p> <p>Sliders adjust continuous range values.</p> <p>Twists (e.g., an arrowhead) are devices that turn up or down to hide or show additional content or menu items.</p> <p>Wells are option matrices, for example, a palette for color selection.</p> <p>Guidance features are comprehension aids, from single objects to full help systems. Common techniques are tooltips (explanations shown when hovering), progress indicators, and the non-interactive status bar which shows information about the status of the application (e.g., printing) and can provide guidance about the purpose of the control in focus. Input prompts are pre-filled, temporary text used with a text box to provide an example or instructions as to what type of input is expected.</p>
Interference effects	<p>The theory defines interference as the negative interaction between new learning and prior learning. Three types are typically addressed: proactive (prior knowledge inhibits retention of new memories), retroactive (new knowledge inhibits retrieval of prior knowledge), and output interference (when recall of specific aspects of information inhibits recall</p>

	<p>of the rest of the associated knowledge).</p> <p>Much of the traditional research on interference has been based on a paired-associate paradigm with a recall measure (Anderson, 1987).</p>
Intuition, Intuitive knowledge	<p>Wild (1938) presents the definition that is still in common use: "An intuition is an immediate awareness by a subject of some particular entity, without such aid from the senses or from reason as would account for that awareness." It can be reliable but not necessarily for the reasons we ascribe to it. It can't be called on intentionally and is not distinguishable from other perceptual or cognitive outputs.</p> <p>Currently, this concept is better understood as knowledge that has become automated as a result of expertise. It requires prior domain knowledge to operate but its origin can no longer be recalled, actions are contextually stimulated, and based on conceptual pattern recognition. Lindstrom et al. (1993), among many, emphasize that widely varied experience of a phenomenon over an extended time is more important than repetition.</p> <p>Swaak and de Jong (1996) define this type of knowledge as arising from interaction with dynamic simulations; it is difficult to verbalize, and is qualitatively different than that produced by traditional expository lectures. They propose that memory access is more efficient and faster.</p> <p>See also Expertise, Tacit knowledge, Implicit knowledge, Analogy and Similarity, Pattern Recognition, Mental Models</p>
Just-in-Time learning (JIT)	<p>Instruction made available at the time of need. Often learning materials are presented online in the workplace task environment in units sized to meet immediate, specific needs. Sometimes classified as a sub-method of Augmented learning where the environment is adapted to the learner in contrast to a scheduled environment such as the formal classroom where training and work are disjunctive. Criticized for its piecemeal approach.</p>
KISS	<p>"Keep it Simple, Stupid!" A common acronym used by designers of instructional materials; it assumes a low user ability level and over-generalizes the simplicity tenets of Cognitive Load Theory:</p>
Knowledge	<p>The process of creating an external representation of knowledge (often tacit), commonly that of experts. The</p>

Elicitation, Capture	<p>results can be portrayed using many techniques, including concept maps and ER diagrams. In large enterprises the output is generally used to improve communications and set expectations, to drive process improvements, and to build expert systems.</p> <p>See Expert Systems, Entity-Relationship Diagrams, Concept Maps, Topic Maps, Mind Mapping.</p>
Knowledge Objective (KELO)	<p>A statement of what knowledge is to be taught, under what condition, and to what standard at an enabling level (most specific level). See Learning objective for details and use in ISD WorkSpaces.</p>
Knowledge structure	<p>Relationship and sequence criteria are known to be a good indicator of changes in a person's conceptual understanding.</p> <p>The importance of evaluating learners' knowledge structures comes from the research on expertise (Chi et al., 1981 and Larkin et al., 1980) which demonstrated that schema-based knowledge structures held in long-term memory are the most critical feature of expert performance. Such cognitive structures allow experts to rapidly categorize incoming information and decide on appropriate actions. (Kalyuga,2006)</p> <p>See also Cognitive Structure, Conceptual Map, Mental Model.</p>
Landmarks	<p>Items that are distinctive or conspicuous (easily identifiable) in the environment due to some physical attribute or perceived high importance or personal interest and used to denote a fixed and known location of interest. A fundamental concept of navigation, used as intermediate waypoints for route planning, orientation, localization (determination of current position), or route description.</p> <p>Landmarks are considered a fundamental unit of cognitive maps by some but not all (see Golledge, 1999). In the context of robot navigation Borenstein et al. (1996) distinguish between natural landmarks which are part of an existing, highly structured environment and artificial landmarks which are put in the environment specifically to enable navigation. Sorrows & Hirtle (1999) classify landmarks along dimensions of visual, semantic, and structural.</p> <p>Vinson (1999) offers guidelines for navigation in unfamiliar,</p>

	<p>large-scale virtual environments based on research about navigation in the real world.</p> <p>See Global vs. Local Navigation, Route Navigation, Cognitive Maps.</p>
Latent learning	<p>Dormant learning that is not immediately evident and is assumed to require representational processes such that it fits into an existing schema.</p> <p>See Incidental Learning.</p>
Learning	<p>The process of encoding new information and skills through association with prior knowledge or patterns. It can be physical, mental, or affective; implicit or explicit, or any combination in any setting. It affects formation and modification of schemas; encoded items can be viewed as more or less densely chunked and qualitatively different based on level of expertise. Learning is generally a continuous activity, ceasing operation, for example, when there is an absence of stimuli, encounters with information that conflict with strongly held beliefs, or where stimuli are not perceptually acquired. The term has been refined by users in every domain and is a fundamental characteristic of organisms. It excludes only those behaviors believed to be genetically encoded. Synonym for conceptual change.</p> <p>Learning effects determined by empirical studies are used to inform instructional theories. Examples of findings include:</p> <p>Facts studied more frequently are recognized faster (Anderson, 1983)</p> <p>Recognition slows as the amount of intervening information increases (Goetz & Walters, 2000)</p>
Learning Management Systems (LMS)	<p>Related to and sometimes interchangeable with Learning Content Management System (LCMS). Typically accommodate only formal learning but beginning to join informal content sources such as wikis, blogs, and discussion forums (Boehle, 2008). A current trend is to integrate talent management capabilities and disparate database contents such as PeopleSoft HR data.</p>
Learning objective (LO, ELO)	<p>Also called 'performance objectives'. The goal of an item of instruction stated in behavioral terms to support assessment in terms of observable outcomes. A 'cornerstone' of instructional technology intended to guide development but</p>

not generally presented to the learner who is likely to find the format confusing (Knirk & Gustafson, 1986). The strict format of an LO statement insisted on by some and poor implementation has often led to criticism and a movement toward other ways of indicating instructional goals.

In ISD WorkSpaces objectives serve as design guides but also provide a critical, systematic and predictable data format used for content mining, revision control, traceability and automatic update functions. Templates offer an alternative to creating goal statements that otherwise tend to vary widely in level of detail, consistency, and usefulness as design blueprints.

Often divided by level, for example, terminal and enabling, general lesson objectives, core (more important) objectives, and/or distinguishes between declarative and procedural acquisition; knowledge and skills. Highly dependent on the practitioner and area of practice.

Knirk & Gustafson suggest the use of the ABCD model to include these 4 components:

- Audience: who is the learner, what level of expertise,
- Behavior: what are the expected, observable actions that indicate learning,
- Condition: the constraints under which the learner must perform,
- Degree: the measurement used to indicate acceptable performance.

Other formats specify learning outcomes using the following components and terminology. Most approaches have significant overlap, differing primarily in terminology and specificity (e.g., Mager, 1984).

Cues: the environmental trigger for the intended behavior. For declarative knowledge, generally 'on request';

Conditions: the constraints under which the learner must perform, for example, from memory without aids, in high winds...

Verbs: in more stringent applications, used to indicate desired learning outcomes in terms of cognitive effort. See Learning outcomes.

Standards: the measurement used to indicate acceptable

	<p>performance, for example, within 2 degrees of beacon signal.</p> <p>In ISD WorkSpaces objectives are at an enabling level for knowledge and skills and follow the second format above. Affective objectives are not explicitly included. Motor skills are included as Skill LOs or SELOs. Templates for declarative knowledge add consistency and embed expertise. The templates do not use verb to express outcomes since conditions and standards already cover this aspect, the cognitive effort is explicitly identified for each template, and most LO writers find this aspect too rigid. Templates are based on project-defined available resources and preferred strategies. Skill objectives are based on generic skills associated with a task scenario and can be automatically generated based on subtask analysis.</p>
Learning outcomes	<p>Refers to the type of competencies the learner develops, typically in terms of skills at different levels of cognitive effort, and usually discussed within a classification scheme. All assume but are not explicitly a deductive teaching approach, presenting simpler information first, then more complex.</p> <p>The best known classification is Blooms (1966) taxonomy of educational objectives, using three categories: cognitive, psychomotor, and affective. Bruner's (1966) is based on developmental perspectives, distinguishes between active and passive, and proposes 3 stages: enactive, iconic and symbolic. Simpson (1966) developed a taxonomy of psychomotor objectives. Krathwohl et al. (1964) developed a taxonomy for affective objectives. Gagne's classification, most influential in ISD, somewhat extends Bloom's taxonomy classification of the cognitive domain (Gagne, Briggs, & Wager, 1988). The following lists Gagne's categories in order of increasing competency with associated verbs (see also Knirk & Gustafson, 1986, p. 89):</p> <ul style="list-style-type: none"> • Verbal Information (fact): State, recite, name • Intellectual skill: Summarize • Discrimination: Identify, recognize, locate • Concrete concept: Classify (by physical features) • Defined Concept: Distinguish (by abstract attributes) • Rule: Apply, analyze, solve, compare (single relationship) • Higher-order rule: Demonstrate, interpret, predict

	<ul style="list-style-type: none"> • Cognitive strategy: Generate, invent (novelty criterion) • Attitude: Choose, adopt, prefer • Motor Skill: Perform, operate
Lesson specification	<p>A text document specifying the learning experience. Equivalent to Jonassen's Courseware Design documentation and Structural Analysis Learning Maps (1988). Typically includes overall lesson goals, teaching points, their sequence, and implementation requirements such as lesson prerequisites, facilities, teaching aids, student manuals, etc. In complex projects a precursor to a storyboard which adds details such as visual layout. Intended as a early review document before proceeding to more expensive development efforts. Often used as a teacher guide without further elaboration or development.</p>
Log files	<p>Also known in navigation research as "dribble files" (e.g., Lawless, 1997). The data collected by an embedded program, not visible to the user, within an application to record user interaction data such as time, sequence of information selected, and the nature of these selections.</p> <p>Such a system is implemented in ISD WorkSpaces.</p>
Long-term Memory	<p>Long-term memory, as compared to short-term or working memory, is virtually unlimited in both capacity and duration. The knowledge we acquire is widely believed to be stored in the form of organized, domain-specific structures called schemas.</p> <p>There is debate as to whether this organization is best described as hierarchical or associative. At the neuronal level traces are not necessarily co-located although physical proximity can trigger recall.</p> <p>Schemas can be generally viewed as cognitive constructs that allow us to treat multiple elements of information in terms of larger higher-level units (or chunks). Conscious, controlled use of schemas requires working memory resources. However, after sufficient practice, use of schemas becomes automated and requires minimal working memory resources (Kotovsky et al., 1985 and Shiffrin and Schneider, 1977). (Kalyuga, 2006)</p> <p>See Automaticity, Expertise, Spreading Activation, Chunking.</p>
Long-term	<p>A cellular mechanism for learning; a long-lasting</p>

potentiation (LTP)	<p>strengthening (lowered activation threshold due to greater sensitivity to neurotransmitters) of the synapse between two neurons that occurs when both are activated at the same time. LTP is accepted as one of the main neural mechanisms by which memory is stored in the brain.</p> <p>See Spreading activation, Place cells, Connectionism.</p>
Low Effort Thinking	<p>The existing schema guides attention; one ignores features deemed unimportant. It is conservative by nature and is likely to increase under conditions of cognitive load and time pressure.</p> <p>See Depth of processing, Durable Learning.</p>
Mental models	<p>Representations of reality, relationships within a system which enable a user to produce mental simulations of the system's actions and develop ways of dealing with it (Borgman, 2088).</p> <p>Norman (1983) describes them as follows: "In interacting with the environment, with others, and with the artifacts of technology, people form internal, mental models of themselves and of the things with which they are interacting. These models provide predictive and explanatory power for understanding the interaction." Norman distinguishes between the system (user interface of the computer), the conceptual model of the system (an accurate accounting of the operation of the UI), the user's mental model of the system, and the researcher's belief about the user's mental model.</p> <p>Mental models can contain visio-spatial, semantic, time-related, and procedural components. They are thought to be constructed through the interaction of the visual and verbal systems in working memory (Schnotz, 2002). They also contain routines, how to get things done and can be used to mentally run simulations to predict outcomes based on prior experience. The richer the model, the more experiences it reflects, the more helpful it is in dealing with uncertainty in a specific domain.</p> <p>Experts' mental models are domain-specific, rich, highly chunked, internal representations of how things work. Their models reflect substantial domain knowledge, integrating function and structure to more rapidly assess relevant features and solve problems. This foundation also facilitates further domain learning. In contrast novice models show a</p>

paucity of interconnected knowledge, chunking, and typically encode mostly surface features of external representations. They tend to form mental models of structure separate from knowledge of function. (cf. Ericsson, 2006; Heiser, Tversky, et al., 2003; Hegarty, 2004; Trumbo, 2006).

Kerr (1990) points out the importance of a structural mental model for navigation in electronic environments but suggests that it isn't always best to train to induce a specific model, that people differ in their ability to form appropriate models for themselves, and that existing models can conflict with presented models. He states the need for empirical studies of the value of supplied vs. independently constructed models. The current study is one such attempt, with existing evidence suggesting that supplying a target model may be best when the user is less likely to form an efficient model independently, such as in an unfamiliar, complex, highly unstructured environment, or where workplace goals require adoption of a specific model.

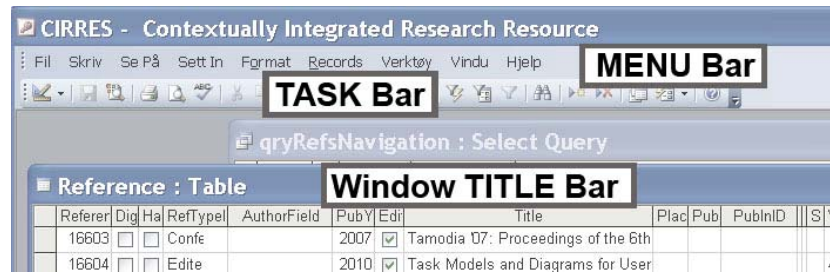
Burgess (1988) suggests that the data organization within a system provides an key entry point for impacting the mental model being built. Kearsely (2008), among others, suggests this concept is especially applicable to procedures since it describes how people understand events and physical relationships.

van Merriënboer (2001) suggests that mental models are a good theoretical construct for improving the synergy between his three-world concept of Knowledge, Learning, and Work. Otter & Johnson (2000) offer a new approach to designing such systems, based on the mental models of users.

Lynch (1960), in the context of architecture, proposes that mental maps consist of five elements: (1) paths: routes along which people move throughout the city; (2) edges: boundaries and breaks in continuity; (3) districts: areas characterized by common characteristics; (4) nodes: strategic focus points for orientation like squares and junctions; and (5) landmarks: external points of orientation, usually an easily identifiable physical object in the urban landscape. Of these five elements, paths are especially important according Lynch, since these organize urban mobility.

Mental Model is generally equivalent to 'schema' and is interdependent with categorization and analogical processes.

	<p>Dedre Gentner (2000) has been influential in developing these concepts.</p> <p>Halford (2007) states: “conceptualize a relational schema as a type of mental model (Goodwin & Johnson-Laird, 2005; Halford, 1993; Johnson-Laird & Byrne, 1991, 2002; Markovits & Barrouillet, 2002). A mental model is a type of analog in that it comprises a display of entities that represent relations that are essential to the structure of the task and that permit inferences to be made. Relational schemas are mental models with the following additional properties. There is a symbol for the relations that are represented. There are access functions so that the components of a relational representation can be retrieved. Relational schemas tend toward internal coherence. Relational schemas are meaningful, in that their elements and relations have referents that can be identified by users of the schemas.</p> <p>... the processes of forming initial, content-specific representations of instances of the structure, recognizing structural alignments, and recoding to a more abstract form might overlap during the learning process, but for any instance they would have to occur in that order. "</p> <p>Abstract symbols have no meaning unless the relations between them are defined, so a representation of structure is required first. Early mental models are likely to be content specific because they reflect attempts to organize material to enable predictions to be generated. Halford (2007)</p> <p>See also Knowledge structure, cognitive structure, Spatial mental models, Awareness, Expertise.</p>
Mental rotation skill	<p>The ability to mentally rotate a visual representation of an object; associated with spatial ability. This skill is essential to recognizing objects, especially when moving or in alternate configurations. It is a key topic in navigation research and location orientation. Speed criteria are generally used to assess skill.</p> <p>See Navigation, Spatial memory & cognition.</p>
Menu	<p>A primary interface device to list commands available to the user such as those used to navigate between locations in an electronic environment. Traditionally these controls have been text lists, as modeled in this thesis by the WIN treatment.</p>



Early research focused on breadth vs. depth issues. Cockburn (2007) has proposed a predictive model of menu performance to fill the gap in theoretical modeling. Menu types continue to evolve. Common examples include:

Accordion: used to move among main sections of the navigation menu while being able to quickly select a related subsection. A main menu item expands to show its submenus by clicking on the main menu or temporarily by hovering. Typically used to conserve space. The WEB menu is an example.

Drop-down: The menu bar is one of the most common formats in use. Each item opens a submenu panel with a list of related items. If more than one submenu panel is required, cascading menus are typically used.

Cascading: Also known as a hierarchical or child menu, it is a submenu or set of submenu lists that progressively display by hovering over a selection. An arrow to the right of a menu option indicates an additional submenu. Very commonly used despite Microsoft's (2001) caution to use sparingly due to the coordination necessary to operate. The WIN menu is an example.

Pop-up: A menu panel that displays in a secondary window when the user right-clicks over an interface object. It provides commands that affect the current view. If the cursor is in a table, for example, the menu might include Insert table, Split cells, Auto-fit, etc.

“Usable and effective menu organization depends more on the types of tasks and the domain of knowledge than mere menu organization, although menu organization is a factor in the process.” (Ju, 2005) [Argument for basing on target mental model].

See Navigation, View Navigation.

Mere exposure	<p>Zajonc's (1968) "mere exposure" effect describes the influence of familiarity: repeated exposure to a stimulus is sufficient to improve attitudes toward that stimulus. People tend to favor more familiar things. Exposure increases familiarity, thus influences preferences and a sense of comfort or safety more than logical assessment. This effect is strongly exploited by marketing efforts.</p> <p>Straub (2004) suggests that "efficiency of task completion may not be the holy grail in e-tail environments. In bricks-and-mortar retail environments, being exposed to something increases your likelihood of buying it. Further, the longer you browse, the more you are likely to buy. It is reasonable to believe that these same effects hold in on-line environments."</p> <p>The results of Hansen & Wänke's study (2010) suggest that repeated exposure affects attitude formation independently of conscious recognition and stress the role of unconscious familiarity in attitude formation.</p> <p>See also Priming.</p>
Meta-data	<p>Generally defined as "data about data". In information science it is "data about documents" used in information retrieval. The best-known vocabulary for metadata is Dublin Core which specifies a set of 13 properties. Garshol (2004) defines meta-data as "any statement about an information resource", regardless of what it is being used for, which metadata vocabulary is being used, and how the metadata is represented and concludes that the most useful meta-data are keywords. The term 'vocabulary' as used in this context is 'a set of properties' for an object or document.</p>
Mind mapping	<p>A representation about the user's thoughts on a single topic, usually characterized by speed and spontaneity; a way to note ideas during brainstorming. It is often restricted to radial or tree-like hierarchies.</p> <p>The term was introduced by Buzan (1994) to describe a technique used in research on note taking which found that if learners write down keywords as they study, retention was enhanced. Evolved into the commercial product 'Mind Maps'.</p> <p>See Concept Map, Topic Map.</p>
Model-based interface design	<p>A design approach that attempts to map abstract task models into concrete interface designs. According to Puerta (1998) it is one of the least understood parts of model-based</p>

	technology.
Model-facilitated learning	A concept-mapping approach for designing instruction that integrates new approaches and tools for schema induction as proposed by J. Michael Spector (2008).
Module	In ISD WorkSpaces it is a lesson segment, a stand-alone instructional unit that is designed to satisfy one or more learning objectives. A separate component complete within itself that can be taught, measured, evaluated for a change, bypassed as a whole, or re-used in other lessons when content is not highly contextual. Not directly comparable to Reusable Content.
Multiple-select interactions	Like multiple-choice questions but may have more than one correct answer, all of which must all be selected. Straub (2004) states that users do not seem prepared to learn multiple-select interactions on their own.
Navigation	<p>Purposeful movement through space. Physical vs. electronic differences can be classified by differences in size of the presented space (mobile devices vs. virtual worlds vs. physical surroundings vs. map overviews) and the type of tools available to perform, assist, and orient movement. In online environments various forms of menus are used for navigation. Examples include the traditional MS Windows drop-down menus, tabbed menus (based on a file folder analogy), accordion menus common in websites. Navigation is also accomplished with hyperlinked text within page content. In task-based applications, command buttons can include navigation as part of their response.</p> <p>CHI 97 Workshop report (Jul & Furnas, 1997) present distinctions felt to be part of any definition of electronic navigation (with a focus on information search):</p> <ul style="list-style-type: none"> • Searching: The task of looking for a known target. • Browsing: The task of looking to see what is available in the world. • Querying: Submitting a description of the object being sought (for instance, using keywords) to a search engine which will return relevant content or information. • Navigation: Moving oneself sequentially around an environment, deciding at each step where to go. <p>A taxonomy of navigational subtasks was also presented:</p>

	<ul style="list-style-type: none"> • Locomotion: Mechanics of moving a single step. • Steering: Mechanics of controlling each step of locomotion. • Traversal: Stringing together sequences of steering steps to move larger distances in a world. • Route following: A traversal involving accurately following a deliberate path, for example, from some given starting place to some final place. • Route finding: Finding a good path, for example, from a starting place to destination, with desired properties for the path and destination. • Map building: Constructing a representation -- mental or physical -- with spatial structure to aid multiple route following and finding tasks. • Orientation, aligning one representation of the world with another, plays a role in each of the preceding tasks <p>Jul (2004) later identifies a four-part, interdependent cognitive task model of navigation: Locomotion (movement between distinct locations), wayfinding (decision making about path), Spatial knowledge preservation (storing retrievable knowledge about places), and Information-gathering (the collection of information about the environment).</p> <p>See Wayfinding, Menus, Navigation interface, Navigation aids, View Navigation.</p>
Navigation aids	<p>Ways of making environmental features more visible, techniques that support movement through space. Also known as wayfinding aids.</p> <p>In physical space these include signage and landmarks. Kerr (1990) provides an early view of cueing strategies and stresses their importance to the user's ability to form a mental representation of the structure of the space. Cues can include text and text labels; icons, symbols, and images; and perceptual details such as color, shape, and form</p> <p>In electronic environments aids are most prevalent in virtual environments where examples include a view-in-view map, animation guide, and human system collaboration. On the web, breadcrumbs are a common orientation method. Keywords can form the basis of menu items and are a primary search aid in locating a desired destination, but must</p>

	<p>be familiar to the user in the context of use. Kerr (1990) points out that this is problematic for novices in a domain.</p> <p>Park & Kim (2000) examined aids in the form of two types of contextual information, structural (supports forward navigation) and temporal (supports awareness of path taken, backward navigation).</p> <p>Schematic maps are also considered a type of wayfinding aid (Freksa, 1999).</p> <p>See Disorientation. Breadcrumbs serve a temporal function.</p>
<p>Navigation interface</p>	<p>The menu, or more broadly, any part of the user interface which provides user-controlled movement through different screens, pages, forms, or spatial environments such as virtual reality or online gaming environments.</p> <p>Discussions of navigation in online environments often use a map metaphor to describe geographic orientation and cyber-movement, semantic linkages (e.g., concept maps) but outside gaming environments, the actual use of a map-like representation for domain navigation is a rare occurrence in interface menu design. Cikić (2008) suggests one reason is that sites lack an underlying geography or structure, conceived as “as unstructured (or at most hierarchical) addresses.”</p> <p>McDonald’s (1998) findings for the effect of prior knowledge on navigational approach showed that a map condition was superior to that of the contents list and while expertise mattered in other interface types, there was no difference in the map condition. While less expert users used navigational aids more, it was primarily during browsing rather than goal-directed tasks.</p> <p>A current interest in navigation design is personalization (e.g., McGrenere, 2007) and automatic adaptation, with Microsoft’s ‘contextual’ menu as a less successful example (item position changes based on use frequency).</p> <p>Van Welie (2008) provides a taxonomy of navigation interface patterns. See Design patterns.</p> <p>Kerr (1990) points out that the effect of training decays fairly rapidly, referencing Borgman’s 1986 article on the difficulty of using online catalogs in the early years of widespread computer use..</p>

	See Menu, Navigation (Physical vs. electronic differences).
Navigation path	<p>The sequence of user-controlled movement through an application or website using the navigation interface.</p> <p>A method using time spent and choices made to assess the utilization and efficiency of learner controlled movement and thus knowledge acquisition strategy, information search and problem solving (e.g., Lawless, 1997).</p> <p>Straub (2004) points out that user behavior has changed. “3 clicks to service is not required, as long as the navigation path accurately reflects and reinforces the user's information model.”</p>
Non-formal learning	The opposite of formal learning. See also ‘informal learning’. Coombs and Ahmed, 1974; Mocker and Spear, 1982; Jarvis, 1987 all use this term to distinguish among formal, informal, and nonformal learning. Eraut (2000) prefers this term to distinguish between implicit learning, reactive on-the-spot learning and deliberative learning.
Ontology	<p>In philosophy it is the study of the nature of reality, what entities do or can exist and what are their relations.</p> <p>In computer science and information science an ontology is a formal representation of domain knowledge. Garshol (2004) defines it as “a model for describing the world that consists of a set of types, properties, and relationship types – a type of classification language for describing a subject. Shanks, Tansley, & Weber (2003) states that theories of ontology lead to improved conceptual models and can help validate that embedded representations in applications are faithful to their focal domains.</p> <p>Ontologies use an open vocabulary and thus differ from Controlled vocabularies, Taxonomies, and Thesauri which all use closed vocabularies. ISD WorkSpaces uses a controlled vocabulary.</p> <p>See Schema, Conceptual Model, and related terms.</p>
Overview map	<p>A visual site map as used by Sjölander et al (2005). It presented a static view of an interactive 3D environment (a grocery) and was used like an advance organizer and navigation aid but not for navigation itself.</p> <p>In ISD WorkSpaces, the MAP menu meets both goals.</p>

Paired-associates	<p>A paradigm with a recall measure; used commonly in traditional research on interference effects in memory. Two lists are developed that involve the same stimuli but require different responses. The list items are assumed to focus attention and create a memory trace connecting the stimulus, the response, and the context. activate relevant memory elements if they exist.</p> <p>This is an common example of the type of context-free, laboratory-based research typical in memory research.</p>
Pan & Zoom	<p>A multi-point interaction technique that requires the display to be scaled large enough for manipulation while also efficiently navigating to alternate control points. This technique is particularly applicable for large or full-screen graphical interface maps and an option for large menus. An example is the flightline instructional simulation Virtual Workplace which allowed navigation within an office and out to all locations on a parked aircraft (Swanson, 1995).</p> <p>Also used in visual representations of large information spaces.</p>
Path integration	<p>The ability to estimate one's current position and orientation relative to a starting point. This requires an internal representation of the direction of motion.</p> <p>See Spatial Ability, Navigation.</p>
Patterns, pattern-matching	<p>A fundamental feature of memory. Patterns are organized subsets of perceptual phenomena, event sequences, or neural states. In psychology they are an alternate way of discussing schemas. Pattern matching is a form of classification, looking for similarities to decide whether or not a concept or object matches a</p> <p>In software and other fields, they are act as a preferred template. See Design patterns.</p> <p>See Schema, Spreading Activation, Neural Networks, Analogy, Configural learning among others..</p>
Perception	<p>The ability to receive and process sensory information.</p>
Physical vs. electronic navigation	<p>See View Navigation</p>

Picture perception	<p>The reception and encoding of visual input of a representation; a symbolic optic array which causes the viewer to construct a related meaning. Related terms: graphics, images, visual media, symbol systems. Realism is the degree to which a picture matches the object it represents in the everyday environment. This perception is mediated by influences; it is not always a direct translation of the retinal image.</p> <p>Gestalt theory classifies images by how elements are organized: similarity, closure, symmetry, common fate and continuity. Current views of visual perception are influenced by David Marr's 3-level theory of vision, a computational model.</p> <p>Levie (1987) suggest that pictures present two types of information: specific features such as objects and cues) and holistic (the schema, the global meaning somewhat independent of the specific details). Factors affecting picture interpretation include imagery ability (also called visual ability), age, culture, verbal ability, field dependence, and familiarity. Differences exist between recall and recognition of images.</p> <p>Pictorial cues that assist in interpretation include: shape and contour, color, boundaries, lines, curvature, surface texture, shading to show depth, figure-ground discriminants such as shadowing, element relationships (grouping/layout), size (can indicate importance), element sequencing/orientation (can show time or motion), perspective, and truncation of the visual field. The presence of distinctive features improve perceptual processing. Visual analogies can facilitate learning of abstract concepts by making them more concrete.</p> <p>See also Spatial memory & cognition.</p>
Picture superiority effect	<p>Concepts presented visually will be recalled more easily than with words.</p> <p>Hamilton & Geraci (2006) found that a picture superiority effect occurred only on a conceptual test using distinctive cues, supporting their hypothesis that this effect is mediated by conceptual processing of a picture's distinctive features, not a picture's semantic features.</p>
Place cells	<p>One of several types of spatially activated neurons in the hippocampus. These fire when a person (or rat) is in an</p>

	<p>environment the place cell is sensitive to (its place field). Other cells with spatial functions include as grid cells, border cells, head direction cells, and spatial view cells.</p> <p>See Hippocampus.</p>
Plan Monitoring	See Navigation.
Primacy Effects	A cognitive preference; information presented first is recalled more easily than information presented later. Primacy effects are enhanced under time pressure (Kruglanski & Freund, 1983)
Priming	<p>A tendency of implicit memory where exposure to a stimuli temporarily increases the activation strength of associated memory traces such that these are more likely to be retrieved in the reception, interpretation of, and preferences for subsequent stimuli judged similar. Priming can improve performance while reducing processing requirements. (See Cognitive Load Theory). Typical priming test include naming, lexical decision, or Stroop tasks, as well as paired-associate recall or sentence recognition. Anderson (1983) makes the claim that regardless of the priming mechanism used to cue retrieval, the same spreading activation mechanism is involved in memory retrieval.</p> <p>Priming is strongest when the two stimuli (source and target) are the same sensory mode, for example, visual sources prime visual targets. Priming can increase or decrease speed of processing and is sensitive to a match between the semantic categories of source and target, feature matches, and associations generally. Squire et al. (1987) found that normal subjects exhibited larger and longer- lasting word completion effects when tested under a semantic orienting condition than when tested under nonsemantic and that these effects could last up to 4 days. Hamann (1990) found that category exemplar priming declined rapidly over a 90-min interval, and elaborative study conditions enhanced the duration of priming.</p> <p>Dehaene et al. (1998) showed that semantic priming effects occur implicitly with masked priming where visual words are presented so briefly (43 ms.) that they can't be seen but still facilitate processing of related words.</p> <p>Examples of perceptual priming are word-stem or word fragment completion tasks where words completed by</p>

	<p>subjects more frequently match studied list than not. Conceptual priming uses lexical decision tasks where subjects more quickly respond to words that are semantically similar to a presented word.</p> <p>Semantic priming refers to the effect as well as technique used in the study of semantic memory, linguistics, as well as implicit memory and learning. This effect is evident when subjects respond faster to a target word when it is preceded by a semantically related word compared to an unrelated word.</p> <p>Negative priming refers to an unfavorable response due to prior exposure, that is, changing a previously ignored object to a selection target will slow response time. It is a side effect of inhibiting irrelevant or distracting stimuli that might otherwise interfere with cognitive processing.</p> <p>Structural priming Chang (2002).</p> <p>See also mere exposure effect.</p>
Prior knowledge	<p>David Ausubel (Ausubel, 1968) emphasized on the importance of prior knowledge in being able to learn about new concepts. Drawing on this theory, Novak (1993) concludes that existing cognitive structures are critical for learning new concepts.</p>
Problem-based learning	<p>A more inductive teaching method where complex, ill-structured, open-ended real-world problems provide context for learning.</p>
Procedural knowledge	<p>Knowledge of specific skilled behavior that describes how declarative knowledge is used. It interrelates schemas (built on declarative knowledge) which are then used to guide and predict performance; these schemas are therefore sometimes called performance schemas. These are characteristic of more complex activities. Also called scripts by Schank & Abelson (1977).</p> <p>Procedural memory is memory for how to do things, part of long-term memory and generally classified as implicit since it requires no attention or awareness. Memory for facts (semantic) and events (episodic). Often used interchangeably with procedural memory. It is one of the memory modules in ACT-R.</p> <p>See Propositional and Declarative Knowledge.</p>

Process Dissociation Procedure (PDP)	Introduced by Jacoby (1991) to distinguish between the contributions of conscious and unconscious knowledge to task performance. This focus on process is in contrast to methods identifying different processes with different tasks and treating the task as a valid measure of the process. Tasks used to demonstrate memory dissociations are considered by Jacoby to be parallel to those of used in studies comparing automatic and controlled processes in the attention literature.
Process Purity	An issue related to the ability to measure unconscious processes such as incidental or implicit learning. Both explicit and implicit processes are assumed to operate concurrently, defeating the approach of trying to define 'process-pure' tasks such as the SRT tasks used to investigate sequence learning (Curran, 2001).
Production	A formal notation in Anderson's ACT-R architecture that represents procedural or operational knowledge and specifies signal flow from those information buffers to other modules and back. It reflects a perspective on neural activation proceeding from cortical areas to the basal ganglia and back. Memory modules use an internal pattern matching algorithm to locate a relevant production to execute. This can modify the memory buffers and changes the state of the system. The operations do not reference meaning as such, are syntactic only, thus ACT-R is classified as a symbolic rather than connectionist computational system.
Project-based learning	A more inductive teaching method where major projects provide context for learning and the end product is generally a formal written and/or oral report.
Propositional knowledge	Knowledge of facts, ideas, propositions. Describes 'what' but not 'how' (see Procedural knowledge). The type of knowledge generally referenced by epistemology, with a focus on the properties of a given entity. Also called Declarative knowledge. Cf. Declarative memory.
Prototype schema	Defined by Hastie (1981) as a schema that reflects an "average composite" abstracted from a set or related items.
Random walk	A measure of navigation performance. A large number of trials through an environment are performed between a

	<p>defined start point and end point, allowing movement along any valid path until the end point is reached. The mean of these trials is compared to an expert or optimum path to calculate a navigation performance score.</p>
Reactive learning	<p>A term introduced by Eraut (2000) to describe 1 of 3 types of non-formal learning modes. The learning is explicit but unplanned. It “takes place almost spontaneously in response to recent, current or imminent situations without any time being specifically set aside for it.” (p.115)</p>
Recency effect	<p>An effect of cognitive processing that causes more recent memory traces to be recalled more readily than earlier traces. The primacy effect refers to the inverse. Collectively called the “serial position effect”. Together they predict that, in a list of items or series of events, the earlier and later ones will be more easily remembered than those in the middle.</p>
Recommender system	<p>Collaborative software functionality embedded in websites to support user choices using algorithms based on collective past choices and preferences to offer recommendations.</p> <p>Contrasts with content-based recommendations. In online product websites Ochi et al (2010) identifies three trends: a shift from characteristic-based to social-based recommendation algorithms; more complex algorithms; and greater use because online products cannot be examined for quality before purchase.</p> <p>See also Interfaces agents and Intelligent user interfaces.</p>
Relational schema	<p>A mental model of the structure of a task. A structural theory presented by Halford & Busby (2007) to expand the definition of implicit learning beyond that based primarily on artificial grammar studies. Relational schemas are defined as mental models with the addition of an explicit symbol to indicate the transformation of one instance from an initial state to an end state (dynamic relationship), a binding that preserves the truth of a relation (structural alignment), omnidirectional access functions to retrieve relational components, and predictive capability.</p> <p>Schemas are characterized by internal consistency and identifiable referents (by users) – meaningful in the contexts in which they occur. It is a structural approach in that meaning emerges from acquiring a representation of the structure.</p>

	<p>Non-structural schemas theories include Configural learning. See also Structure mapping, Structural alignment.</p>
Retrieval	<p>The memory process of recalling or recognizing prior information and experiences as a result of sensory inputs (experience with the external world) or self-initiated thoughts. It is activated through association with the contents of working memory. Retrieval is sensitive to those association strengths set by initial encoding and subsequent recoding, that is, context.</p> <p>Retrieval is considered evidence of learning but not definitive for retention. When stored information is retained but not reliably retrievable in relevant situations it is called inert knowledge (CTVG, 1990; Crews et al., 1997).</p> <p>See Encoding, Chunking, Spreading activation.</p>
Revisitation	<p>A navigation style reflecting the number of times a person returns to the same web page repeatedly during an information search. A metric for assessing navigation performance.</p> <p>A high revisitation rate is associated with "laborious" or intensive which can indicate weak spatial ability and low search expertise. It can also reflect trial-and-error navigation which does not relate to disorientation and does not necessarily reduce performance. It may be a strategy to compensate weak spatial ability (Juvina & van Oostendorp, 2006).</p> <p>See also Flimsy Navigation, Content Focus, Divergent Navigation (Juvina & van Oostendorp, 2006).</p>
ROSA	<p>An LCMS that provides users with a conceptual map view of courses. The ROSA data model is designed as an extension to the RDF data model with ordered collections, relationship properties and cardinality constraints (Porto, 2007).</p>
Route knowledge	<p>Knowledge about the sequence of steps (objects or events) needed to reach a designated location or goal. Werner et al. (1997) call this a feature of tactical navigation. They contrast this with elementary navigation which is highly task-dependent and with strategic navigation which requires planning and survey knowledge of landmarks. Route knowledge is gained through direct exposure or through</p>

	<p>reference to an existing schema.</p> <p>See Navigation, Landmarks, Mental models.</p>
Scaffolding	<p>A stepping stone, learning aid for acquiring new knowledge. As in the building trade, psychologists speak of scaffolding as a temporary support to be removed as the learner gains confidence and expertise. Generally assumed that the higher the domain knowledge of the learner, the less scaffolding required.</p> <p>Bruner introduced Scaffolding Theory in the context of language acquisition with a focus on categorization.</p> <p>Houdeshell (2004) provides an example of concept maps used to scaffold transfer activities to enhance adaptive problem solving.</p> <p>Metaphors are a favored interface design approach intended to provide scaffolding but are not removed over time, for example, , desktops, tabbed files, and maps.</p> <p>The expertise reversal effect suggests that after the initial learning stages, scaffolds can inhibit expert development.</p>
Schema	<p>An alternate term for mental model or knowledge structure. Plural: schemata, schemas. The term is used extensively but rather inconsistently in cognitive and social psychology to refer to a flexible, cognitive pattern of related concepts and actions that develops over time as we interact with the world. The work of Vygotsky (1986) asserts that interaction with the external world influences the way such internal, mental structures are formed and operated; that organisms are not independent of their environments.</p> <p>A network of associations. A conceptual structure that organizes knowledge; a functional organization of perception, memory, and cognition. Used to infer contextual characteristics based on previous stimuli, guiding expectations and decisions, and predictions of the outcomes of future actions. Usually formed automatically, without explicit intent, and subject to restructuring but relatively persistent and resistant to change. Influences attention. Schema are based on interpretation of personal experience and thus prone to incompleteness, distortion, misconceptions, and errors. Existing schema can interfere with new learning.</p> <p>Gobet (2005) discusses the importance of variability in</p>

	<p>acquiring schemas.</p> <p>Hummel & Nadolski (2002) demonstrate the importance of schema in problem-solving activities and discuss task-valid cueing which facilitates (1) task performance in complex learning environments, (2) schema construction, and (3) monitoring.</p> <p>Hypertext researchers contend that the information structure should reflect memory structures. By empirically deriving and then mapping the semantic structure of information onto hypertext and explicitly illustrating that structure in the hypertext interface will result in greater changes in the knowledge structures of the users (Jonassen, 1990, 1991b; Lambiotte et al., 1989; McAleese, 1990; McDonald, Paap and McDonald, 1990).</p> <p>Computer science also uses this term for the models that represent the abstract concepts of a software system's architecture, modeling of database entity relationships, xml data, and other information systems.</p> <p>In this dissertation it and related terms like conceptual model are used to reference human memory processes as well as the representation embedded in the application that is intended to reflect a real-world knowledge domain.</p> <p>Related terms: Semantic Network, Conceptual Or Cognitive Map</p>
<p>Schema induction</p>	<p>The process of forming or refining a schema when encountering new knowledge or experience. Also activation of an existing schema based on perceived similarities to current conditions or information and context or accessibility.</p> <p>Meaning can be induced as experience with the materials is accumulated; meaning emerges from acquiring a representation of structure. Schema induction can start with implicit, unconscious learning of the links between elements, which enables recognition of patterns of covariation (Reber & Allen, 2000). Real-life acquisition of structured knowledge may go beyond this and involve active processing. WorkSpaces tasks provide that active involvement.</p> <p>Representation of a relational schema permits analogical reasoning. (Halford & Busby, 2007). Their studies have shown that the schema induction paradigm is a powerful way to induce knowledge of structure from initially meaningless</p>

	<p>but potentially meaningful material without direct instruction in the nature of the structure.</p> <p>If new information does not fit existing schemas, it can be ignored or quickly forgotten so prior knowledge is an important factor in learning. Halford & Busby (2007) point out that “A mental model of the structure enables inferences to be made, so requiring inferences that accord with the structure is a good way to induce acquisition” (p.588).</p> <p>See Piaget’s terms Assimilation and Accommodation for his account of schema re-use and change. Also Task representations, Category learning.</p>
Schema Theory	<p>Bartlett (1932) is credited with first proposing the concept of schema. Schema-like constructs form the basis of many theories of cognition including: Schank (scripts), ACT (productions), Soar (episodic memory), Piaget, and Rumelhart & Norman (modes) as well as some instructional theories such as Bruner, Reigeluth, Spiro and Sweller.</p> <p>Early proponents Rumelhart and Ortony (1977) contend that knowledge is stored in information packets, interrelated information organized into a conceptual unit. Schemas have attributes which can consist of other schemas. Theories of schema induction stress the importance of multiple examples. It is not the number but the kind of differences between multiple examples that determines the acquisition of knowledge.</p>
Script	<p>Used by Schank to describe schemas that guide behavior in stereotypical events. Also called an ‘event schema’ (Mandler, 1985).</p>
Scroll bar	<p>A software interaction object that is either horizontal or vertical, used to move to/display sections of the screen or window hidden due to real estate limits. May be used if navigating to another screen or page would be disruptive to attention. Horizontal scroll bars can interfere with fluid reading when text is not automatically shifted to fit the window.</p>
Search Engine	<p>An application like Google and Bing that takes keywords as input to return a list of addresses for related information sources on the internet.</p> <p>Limitations include the need for users to know or guess appropriate keywords, return sets can be unmanageably</p>

	<p>large, and there is little guidance available.</p> <p>Various visualization techniques are available to filter results but few have made it into general use.</p> <p>See Navigation.</p>
Semantic network	<p>Describes the organization of schemas as a network of nodes and links (relationships), arising out of a computational approach to memory (Norman, Gentner and Stevens, 1976).</p>
Sequence learning	<p>Bennett et al (2007) define this as acquisition of a pattern or regularity within a series of stimuli from environmental input (i.e., speech and nonverbal social cues) without awareness of what has been learned. They explored whether there might be limits to the level of sequential structure that older adults can learn implicitly. They found that older adults remain sensitive to highly complex sequential regularities in their environment, albeit to a lesser degree than younger adults.</p> <p>Fu, Dienes, & Fu (2010) claim that judgment and structural knowledge methods of testing for implicit learning dissociate in sequence learning and may not be as unconscious as thought.</p> <p>See Structural Knowledge.</p>
Serial Reaction Time (SRT) tasks	<p>Used extensively in implicit memory and learning research (e.g., Ash & Nokes, 2003); uses artificial materials and motor skills. The sequences, connected series of events, that are embedded in the SRT tasks engage processes that guide the temporal organization of behavior, the formation of high-order associations, and the prediction of future events. Some question its utility as a measure of implicit learning.</p> <p>Participants select a response to a series of simple visual cues. Cue position can be either fixed or varied, presented randomly or in a repeating sequence. Response time data, generally improving over time, is an indication of learning, not only of the sequence but the visio-motor mapping between cue position and response. A more specific measure of skill learning – and one that minimizes the possible contaminating influences of factors such as fatigue and motivation - is to contrast the sequential response times against those for the random trials. Since awareness is used to determine whether learning is implicit or explicit, an advantage of this method are the number of techniques available for measuring this. By</p>

	<p>contrasting between conditions of explicit and implicit sequence learning, it is possible to gain insight into the effects of awareness (Robertson, 2007).</p> <p>See also Artificial grammar, Implicit learning.</p>
Situated learning	<p>A socially-based theory that stresses the importance of the context of actions. It contrasts with the cognitivist view that learning is objectively definable and results from personal information processing. Situated approaches contend that knowledge is a product of the activity, context, and culture in which it is developed and applied. It is a collaborative effort: meaning is negotiated between teacher, student, and the environment.</p> <p>Knowledge and skills should therefore be taught in contexts that reflect how the knowledge will be used in real-life situations (Brown et al. 1989). Stresses the importance of reflection for behavioral change, proposes that a cognitive apprenticeship approach (Collins et al., 1991) best supports the situated nature of knowledge. There is strong evidence that recall is influenced by context of the initial event (e.g., Bransford & Johnson, 1972) and similarly, that testing in a different context than the related learning degrades performance.</p> <p>Suchman (1987), an anthropologist and influential proponent of situated actions, argues that actions occur in the context of particular circumstances and plans or goals are vague since they must accommodate unforeseen situations. Rational statements of goal in many circumstances are likely to be reconstructions rather than present prior to actions, a result of a cultural bias.</p> <p>The Lave & Wenger (1991) model of situated learning define learning as a process of engagement with a 'community of practice', a tuning of relationships between persons and the world. Some communities are formal, others fluid and informal. It is this engagement that can be viewed as the basis for implicit learning although they did not explicitly use that term.</p> <p>Anderson, Reder and Simons (1996) have criticized claims of this model as not being extensible to more complex tasks. They also argue that the <i>type</i> of learning affects whether it is bound to the context or not, that individuals <i>do</i> learn outside the social context, it <i>is</i> effective to teach abstractions as long</p>

	as concrete examples are used, and that transfer of knowledge from one context to another <i>does</i> happen (albeit with difficulty).
Situation awareness (SA)	<p>A person's momentary knowledge of the surroundings and his or her presence in it. Neerincx et al. (2001) define 3 levels of SA that affect navigation performance: Perception of environmental elements, the comprehension of their meaning, and the projection of their status in the near future. The complexity of the first can result in orientation difficulties. A lack of comprehension can lead to a mismatch of actions and goals. An adequate mental model or schema is required for prediction and problem-solving at the projection stage.</p> <p>This attribute is also a part of the DIF analysis model. See Attention, DIF Analysis, Schema, Mental model, Navigation.</p>
Skill, Skill Objective (SELO)	<p>Generally poorly defined in relation to knowledge with idiosyncratic interpretations as to whether a skill is both mental and physical, procedural activity or declarative knowledge, etc. Skills are generally associated with procedural memory and require practice (but not only simple repetition). A skill is affected by the size and breadth of the supporting knowledge store and by individual processing capacity. Schemas are critical to skill acquisition as they are for any learning.</p> <p>As used in ISD WorkSpaces a SELO is the specification of how to teach a single, integrated, generic, physical activity such as operating a type of switch or riding a bicycle. It inherits the contextual requirements of the subtask whose performance it is part of, thus there may be several SELOs for the same skill, each describing a different set of cues, conditions, and or standards of performance. For example, bicycle riding performance may be measured by ability to ride in strong wind conditions or only good weather, with an amputation or while carrying a small child. It may itself be supported by specific knowledge objectives such as determining the requirements of a child seat. Considered to be an objective at the lowest 'enabling' level.</p> <p>See Attention/Awareness, Schema.</p>
Snap-Together	A tool to rapidly prototype and produce coordinated visualizations. Developed to support the rapid exploration of complex information. The conceptual model of visualization coordination is based on a relational data model (North,

	2000).
Spatial memory & cognition	<p>An aspect of memory responsible for encoding environmental information and one's orientation within space. Spatial thinking and its cousin visual imagery are an integral part of life and well researched in both psychology and neuroscience. The hippocampus is the primary part of the brain responsible for spatial functions.</p> <p>Ramadas (2009) contends that an principled, evidence-based framework for visio-spatial methods is still lacking in education despite the fact that such approaches are applied broadly, and new methods are continually developed. See Information Visualization.</p> <p>Spatial skills include the ability to single out details, change points of view, visualize rotations in space, and identify embedded figures. (Levie, 1987).</p> <p>Werner et al. (1997) present a taxonomy of spatial knowledge in navigation tasks</p> <p>Tests of spatial ability involve mental transformations such as rotation (e.g., Vandenberg-Kuse test), reflection, scanning and zooming, and perspective change. In physical and online environments test approaches include map interpretation, map drawing, direction giving, orienteering, estimating time to target of distance between locations, orientation, and use of navigation cues such as landmarks. Experimental results are difficult to compare due to wide variation in design and definition. Broadly substantiated findings relevant to e-navigation include:</p> <p>Navigation in electronic environments (e-navigation) is widely accepted as activating most of the same processes as geographical movement in physical space.</p> <p>Spatial ability and memory factors has been found to affect navigation performance, especially in the elderly and in task completion time.</p> <p>Findings of sex differences are inconsistent (e.g.)</p> <p>Spatial context learning (see Contextual cueing) is sometimes contingent on item identity and it is therefore important to consistently use visual cues such as color (Jiang, 2005).</p> <p>Route recall is better with less perceptual detail than high</p>


	<p>(Sanchez, 2009).</p> <p>Spatial visualization ability affects task performance whereas mental rotation ability does not (Sanchez, 2009).</p> <p>Zhang (2008) argues that techniques common to virtual environment, such as scaling, offer more interaction options and can improve the integration of spatial knowledge and spatial actions.</p> <p>See Navigation.</p>
Spatial compatibility effect	<p>Refers to the fact that stimulus response will be faster and more accurate when stimulus and response locations correspond spatially than when they do not.</p> <p>Substantial evidence is available that supports the finding that the orientation of even irrelevant objects provokes spatial compatibility effects. For example, Tucker and Ellis (1998) observed compatibility effects for left–right oriented objects, even if they were task irrelevant. See also Rueda et al. (2004)</p>
Spatial mental models	<p>As described by Jul (p.15, 2004) model development, or “Spatial knowledge preservation”, is the task of encoding and storing spatial knowledge for future need, as well as recalling and decoding such preserved knowledge for current use.</p> <p>Tversky (1993) provides a description of characteristics, concluding that rather than "cognitive map", a better metaphor for people's mental representations of environments and maps is "cognitive collage."</p>
Spreading activation	<p>A cognitive representation. In psychology an account of how factual memory is structured, first proposed by Anderson in 1976 (Anderson, 1983) and since modified and extended several times, for example, ACT-R. Experience establishes a pattern of activation among collections of neurons or nodes. Knowledge is represented as a network of nodes which can represent propositions, images, strings, etc. (see Chunking). Encoding of these units occurs in working memory (WM) where it is transient but has a probability of being transformed into a long-term trace based not on time in WM but on many factors such as repetition, elaboration, and prior knowledge. (Affective influences are not accounted for in ACT.) Traces are assumed to be retained but the strength of the trace may decay, affecting retrieval.</p>

	<p>The continuous nature of activation means that presence in WM is a matter of degree and also determines the level of activity in long-term memory (LTM). Activity in WM may activate traces in LTM to be processed together based on the associative strengths of each element, that is, the activation of any given element spreads to neighboring elements, with the breadth of the activation based on strength of the activation, level of association, or perception of relatedness. LTM memory patterns affect which elements in WM are 'attended' to and how they are transformed into long-term traces. Anderson refers to the function of elements in working memory as foci or 'sources of activation'.</p> <p>Anderson proposes a 'reverberation' effect where once a node is activated, it also influences responses on the node that propagated the activation to it. This functions to strengthen or weaken the association. This explains the observations that an item successfully recalled on one trial has a greater probability of recall on a second trial. Once attention ceases, elements in WM are no longer a focus, and activation decays over the whole network.</p> <p>Anderson posits that formation of links or associations are not subject to interference but retrieval is. This reaction time is a better measure of interference than percent recall.</p> <p>Spreading activation accounts for the strong effect of prior knowledge as well as context effects of environmental and task on schema induction. In this account schemas are tightly associated patterns of activation.</p> <p>The concept is used in artificial intelligence and neural networks and can be viewed as a physical description of neural activity. Spreading activation can also reasonably describe schema and category/analogical learning although it is not commonly applied to to discussions in the latter contexts.</p> <p>See also Hopfield networks, Fan effect.</p>
STAR.Legacy	<p>STAR: Software technology for action and reflection. A software shell for an inquiry based instructional strategy intended to augment instructional practices. It integrates four learning perspectives (environments): Learner, Knowledge, Assessment, and Community. The learner-centered lens highlights students' prior knowledge, skills, and attitudes. Knowledge is organized around core concepts in a discipline.</p>

	<p>Assessment-centered environments help expose students' thinking to identify areas for improvement. The community lens focuses on the social aspects of learning "that capitalize on local settings to create a sense of collaboration" and connection. (p. 40). This integration is referred to as a flexibly adaptive instructional design.</p> <p>The components have been identified as important to implicit as well as explicit learning. Visibility is a key criteria used. Design components include:</p> <p>Represent the model – its components and sequence.</p> <p>Preview the knowledge domain as a technique to help set goals/learning objectives, and orient the learner to the boundaries and contents.</p> <p>Provide the learning context, situate the lessons to anticipate tasks.</p> <p>Motivate through relevancy and personal benefits of the activity, through ongoing visibility of improvement and awareness through reflection, and by visibly giving credit for efforts and contributions.</p> <p>Offer assessment to identify gaps and for later comparison for gains. Encourage reflection.</p> <p>Orient by providing current location and task reminder</p> <p>Facilitate flexibility, variation, and multiple perspectives of activities, for example, task performance, idea generation.</p> <p>Encourage revision as part of task performance; make it readily accessible and easy to do.</p> <p>Leave a tangible legacy of effort.</p> <p>The explicit model is used as an orientation aid. It uses a map interface to indicate both the stages of the inquiry process as well as to show student progress through the cycle. The binoculars preview the knowledge domain and set goals. Mountain images indicate that progressively larger challenges are to be met.</p> <p>(Schwartz et al., 1999).</p>
Storyboard	<p>An explicit, page-by-page (screen), sequential blueprint, draft, or sketch of any text content, audio/narration, layout of visual elements, interaction details and feedback to be used in final production. It allows review before more expensive</p>

	production activities have taken place. Generally reserved for more complex development projects such as computer-based training and films but also useful at any level as a communication aid.
Strategic learning	A term used to describe very focused, job-related training to differentiate from broader educational goals. “Strategic learning aims to generate learning in support of future strategic initiatives that will, in turn, foster knowledge asymmetries that can lead to differences in organizational performance ... characterized by targeted information gathering that relies on diverse experts for interpretation as well as validation” (Thomas, 2001). See Strategic Learning Assessment Map (Bontis et al. 2002) also task analysis as one method of “targeted information gathering”.
Structural alignment	An approach to the study of similarity-based cognitive processes that distinguishes between objects and their relationships. Bassok & Medin (1997) found both supporting and conflicting evidence for this account.
Structural knowledge	The knowledge of relationships between concepts in a domain. A form of knowledge representation, also known as a cognitive structure. Techniques like concept maps, semantic maps, graphic organizers, pattern notes, and network diagrams are often used to facilitate learning. It is sometimes viewed as a component of declarative knowledge together with content (Mitchell & Chi, 1984). Learning this type of knowledge can be facilitated through techniques that go beyond simple recall. Dienes, 2005
Structure mapping	A theoretical framework for analogy proposed by D. Gentner (1983) that defines a mapping mechanism between source and target terms and their relationships. Extended by Holyoak & Thagard in 1997 (Gentner et al, Eds., 2001), proposing that coherency of the analogy depended on structural consistency, semantic similarity (connecting both concepts and relationships), and purpose. The theory has been primarily applied in psychology and artificial intelligence (neural networks).
Structure Of the Learning Outcome (SOLO)	A taxonomy adapted to assess structural knowledge in concept maps. It implies that five levels of inference create structural knowledge. Descriptions of the inference levels are used to develop an assessment scale for procedural

	<p>knowledge. It offers support for the argument that concept maps adequately represent mental models.</p>
Subtask	<p>Part of a task. In ISD WorkSpaces it is the lowest level that is still context-specific. It is the only task level analyzed, using a DIF analysis, identifying which curriculum it is effective or valid for use, and identifying problems or failures that are specifically related to it.</p>
Systems view	<p>An interdisciplinary frame of reference for looking broadly at interacting, interrelated elements or groups of activities as coherent systems. It stresses the dynamic nature of interdependence within a given context. Elements are understood to influence each other and cannot be considered individually without losing validity. Systems theory is a general term for the many, varied, and often domain specific</p> <p>It is particularly interested in issues of complexity and change. Engineering and computing were early adopters of this structured approach. More recently, organizational and learning processes have used this perspective to study human behavior in complex environments. Systems engineering is an approach used in business to integrate business goals and the technical and psychological needs of process and tool users with the interests of customers.</p> <p>It stands in contrast to reductionist approaches that were seen as too specialized and too narrow. The systems perspective counters assumptions that interactions of groups of individuals, structures, and processes are additive, that investigation of the parts can be done in isolation.</p> <p>Von Bertalanffy (1951) is credited as an early promoter and explicator of General Systems Theory (GST).</p>
Tacit knowledge	<p>Polanyi's (1966) term for knowledge gained through implicit learning. Eraut (2000) distinguishes 3 types: tacit understanding of people and situations, routinized actions and the tacit rules that underpin intuitive decision-making. It is gained through personal experience rather than learned from others and is inferred from behavior. In the framework of Sternberg et al (1993) it is 1) the product of general knowledge acquisition abilities and 2) a predictor (important but not sufficient) of everyday competent performance. Nonaka and Takeuchi, 1995 discuss "tacit knowing". Generally considered related but not synonymous to informal</p>

	and incidental learning,
Task-focused interface	An interface organized by task rather than folders and files with the goal of reducing cognitive loading.
Task bar	A MS Windows interface feature used to access and switch between open applications and access global commands through the Start button. Its default location is at the bottom of the screen but is user-configurable. 
Task form	In ISD WorkSpaces this refers to the content part of the screen, that which is not explicitly used for navigation. It contains task-related search criteria controls, data selection and entry controls, list controls, access to related reports and pop-up work areas.
Task Hierarchy	A list of tasks a person must be able to perform. Typically excludes obvious tasks that don't require learning. A contextual, parent-child method of identifying and listing job tasks. In ISD WorkSpaces the lowest level that is still context-specific is the only one analyzed, higher levels provide only a structural assist by arranging categorical slots. See Subtask.
Task representations	Dreisbach & Haider (2009) argue that task representations modulate which stimulus information is processed and which is not. The more the representation helps to distinguish between more salient and less relevant information, the more targeted the focus and unnecessary processing is reduced. Kirschenbaum et al. (1996) present the criteria of ratio and distribution of tool-only operations to distinguish between how much time the user spends on task performance versus tool operation. See Attention/Awareness, Schema.
Taxonomy	A system that categorizes topics hierarchically, for example, XML in computer science. Garshol (2004) points out that use of this term is so variant, at best it means some abstract structure. He uses the term to mean "a subject-based classification that arranges the terms in the controlled vocabulary into a hierarchy without doing anything further." It references only a single relationship, broader or narrower, parent or child.

	An interface menu or file structure is an example of an applied taxonomy.
Theory of relation discovery	A theory developed by Doumas & Hummel (2005) in a symbolic-connectionist machine model, which learns structured representations of attributes and relations from unstructured distributed representations of objects by a process of comparison, and subsequently refines these representations through a process of mapping-based schema induction.
Thesaurus	An extension of a taxonomy; a look-up resource that groups concepts by similarity, a subject-based classification method. In information science it is a formal method, specified by two ISO standards, and an expansion of a taxonomy in terms of the types of relationships that can be described. It is used to expand a query term in online searches by relating sets of words by synonym (same as), hierarchy (parent/child), association (related to – easily overused), equivalency (near synonym), or other methods. Item relationships are typically domain-dependent or context-sensitive except for synonyms. See Classification, Controlled vocabulary, Meta-data, Taxonomy.
Tool bar	A Windows interface object for managing sets of controls that provide quick access to specific commands or options. Specialized toolbars are sometimes called ribbons, toolboxes, and palettes.
Topic Maps	The term for a concept map as instantiated in XML and commonly used to structure websites. ISO/IEC JTC 1 (2002) have published a standards specification. The Linear Topic Map (LTM) notation, a text-based syntax, is an alternative to XTM. As used by Biezunski (1999) describes topic maps as a method for structuring information that is optimized for online navigation and lends itself to automated creation. 14700 - The navigation is realized completely via topic maps. For exploring information Related or synonymous terms: Concept Map, Cmap, Conceptual Map, Knowledge Map, Schema, Visual Navigation.
Transactive learning	Collective, shared group learning, in the context of the workplace and close relationships such as families. Group

	<p>learning here is seen as greater than the individual learning that contributes to it. Based on the concept of transactive memory proposed by Wenger (see Lave & Wenger, 1991) to account for this phenomenon, it includes knowledge of who knows what in a team, where the expertise lies for any given task. Often initially implicit, it becomes explicit with interaction and can facilitate team performance. Related to 'shared mental model' (Stout, 1999) and Distributed cognition.</p>
Transfer	See Cognitive Transfer
Usability	<p>The assessment of how well a UI, website, software function, or other product features supports its intended use by taking into account cognitive and physical user characteristics. The most common assessment criteria are speed and accuracy of task performance and user satisfaction. Although usually conducted in person using a mix of qualitative and quantitative approaches, quantitative, web-based tools that support remote, unmoderated testing of digital interfaces are appearing, for example, http://www.loop11.com/</p> <p>Specific metrics for websites may include task completion rate, number of page views to complete tasks, time per task, most common first click, most common success page, most common fail page, most common navigation path, detailed participant path analysis, improvements over time.</p> <p>Consistency is a considered a key property, extending to the belief that familiar approaches are better than new.</p>
User Experience (UX)	<p>Widely used buzzword in the Human-Computer Interaction (HCI) community to describe user affect and sensation during interactive use of technology. It is intended to broaden usability concerns from a narrower focus on user cognition and performance. Law et al. (2008) notes that this term lacks a shared definition or measurement approach, hindering research efforts and practical application of guidelines.</p> <p>The Nielsen-Norman Group (2011) defines it most broadly: "All aspects of the end-user's interaction with the company, its services, and its products."</p> <p>Hassenzahl & Tractinsky (2006) defines it as a "consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (e.g. complexity, purpose, usability, functionality, etc.) and the context (or the environment) within which the interaction occurs (e.g.</p>

	<p>organizational/social setting, meaningfulness of the activity, voluntariness of use, etc.)."</p> <p>See Human-Computer Interaction, User Interface, Usability</p>
User Interface (UI)	<p>That part of the software code that the user sees and interacts with to communicate with the machine and the hardware used to facilitate that interaction, such as a mouse or keyboard. Interaction objects include the navigation and menu controls, data entry and selection controls, as well as all audio-video elements experienced by the user. Machine feedback to indicate the effects of the user's interaction is critical. Initially called the human-computer interface or man-machine interface, also called the Presentation layer by software architects. Currently the term 'user experience' is preferred by designers over 'user interface' to indicate a broader perspective.</p> <p>Early user interfaces were text-based command strings, replaced by text lists. Graphical User Interfaces (GUIs) are now ubiquitous – even text-based menu bars in Windows usually add this feature in accompanying task bars. Web-based and desktop interfaces, initially dependent on different programming environments and their limitations, no longer need to be conceptually separated.</p> <p>An early framework proposed by Foley et al (1990) specifies four types of knowledge about software, also applicable to UI design: conceptual, semantic, syntactic, and lexical. Each level is progressively less abstract, more orthogonal. The conceptual level is the representation of the task set or domain. The semantic level defines the meaning of each object and intended function – the dictionary. The syntactic level describes rules governing object interaction – the grammar. The lexical level lists the generic components that together form meaningful units – the vocabulary.</p> <p>See also Intelligent User interfaces, Menus. For definitions of digital interface controls, also called widgets, see: Interface objects. Many alternatives to these GUI controls are being explored and developed, especially for virtual reality environments and those Safer (2007) calls 'faceless interfaces': voice (natural language) and audio sounds, gesture, tactile (haptic), and physical presence or location (motion tracking).</p>
Verbs (in Learning	In forming learning objectives, the verb can be used to

Objectives)	specify the level of cognitive processing expected. Gagne proposed 9 levels representing shallow to deep understandings:
View Navigation	In view navigation a user moves about an information structure by selecting something in the current view of the structure. To be effective, the views must be small, moving around must not take too many steps and the route to any target be must be discoverable. (Furnas, 1997)
Visualization	See Information visualization, a more specific category.
Visual interface	<p>The GUI (Graphical User Interface) is a longstanding approach, allowing direct manipulation and extensive icon use. There is continuing interest in spatializing interfaces and the use of analogy and metaphor to drive the imagery. Use of concept maps within an application or website is growing although it has generally not extended to primary navigation interfaces. Many examples in the research literature can be found but fewer in commercial use.</p> <p>PersonalBrain™ (2004), a concept mapping software package;</p> <p>Bollini (2004) presents Designing-X, the design of a biomorphic Web Site based on cognitive maps;</p> <p>Concept maps are proposed as particularly helpful in exploring digital libraries and exposing classification relationships (e.g., Rao, 2003).</p> <p>Lin (1997) offers an example of maps for information retrieval, suggesting their utility lies in low space requirements and their potential to expose semantic relationships of terms and documents.</p>
Visual Navigation	<p>In software design the use of graphical elements as the primary interaction control in menu design, not equivalent to labeled icons as in the Windows task bar. The visualization may be an analogy (the term metaphor is often misused in this context): a pictorially represented comparison whereby new information is related to prior knowledge with the assumption that the new information becomes meaningful and, therefore, memorable. See Analogy.</p> <p>Interest in more visual approaches to menu design – suggested by a move to the more current term, navigation – is strong yet textual approaches still dominate heavily. These</p>

	<p>may be due to more practical issues: text is simpler to work with, requires less expertise, and is much cheaper to develop and evaluate. Mackinlay & Shneiderman (1999) list a number of techniques that can be applied to enhance visual approaches to the navigation interface: direct manipulation, multiple views, lens and distortion, focus+context, and data flow. Freksa (1999) discusses appropriate levels of abstractions for map representations.</p> <p>The SC2AN (2003) group has developed techniques that produce graphical association maps to clarify implicit relationships in documents.</p> <p>Topic Navigation Maps now have an ISO standard that defines a layer of abstract topics and relations between them as a method to organize collections of documents. (see Pepper, 2000; ISO/IEC JTC 1, 2002)</p> <p>Lee (2007) more generally discusses the effects of visual elements on mental modeling in online environments, specifically hypertext.</p>
Visual neglect	<p>An effect where a person claims to not have noticed a stimulus presented outside their visual field (or in a area normally perceived by a damaged section of the brain) but is able to make accurate judgments about it. This neglected information nevertheless influences perception and interpretation of the observed stimuli (Merikle & Daneman, 2000).</p>
Wayfinding	<p>In practice synonymous with 'Navigation' but may be used with less emphasis on goal-oriented behavior or to specify electronic contexts. Kerr (1990) describes three stages: identifying where to find what you want, moving to that location, and then either returning to the starting point or moving on to another location.</p> <p>Jul (2004) discusses wayfinding as a cognitive task of spatial problem-solving and decision making to determine where to go and how to get there (p.15).</p> <p>Most efforts to design support for navigation in electronic environments have focused on facilitating spatial knowledge preservation rather than wayfinding, or how to reduce cognitive load.</p>
Web analytics	<p>The quantitative process of determining visitation and use patterns of pages within large websites for both content and</p>

	<p>advertising; used to support change decisions. Software suites may include statistical packages for conversion rates, bounce rates, and average interaction time and/or visit length. Tools can include software that records each keystroke, mouse movement, and click of users for playback and analysis such as Clicktale, Userfly, and Mouseflow.</p>
Working memory	<p>Previously known as short-term memory. An early, transitory (for a given set of inputs), and continuous processing stage in memory formation between perceptual acquisition of external stimuli and existing memory elements in long-term storage. It contains inputs from current activity, the environment, inferences, current goal information overlaid and heavily influenced by elements retrieved from or activated in long-term memory by the current contents of working memory: (psychologically) schemas perceived as similar and (neurologically) the strength of neural patterns activated.</p> <p>Working memory is regarded as the major information processor responsible for both high-level cognitive processing (such as constructing mental models, integrating different mental representations) and short-term maintenance of information involved in those processes (Baddeley, 1986; see also Shah & Miyake, 1999 for an overview).</p> <p>Working memory is very limited in capacity and duration when dealing with unfamiliar information. For example, we can remember no more than approximately seven serially presented random numbers (Miller, 1956) for no longer than several seconds (Peterson & Peterson, 1959), unless the numbers are intentionally rehearsed. (Kalyuga, 2006)</p> <p>See Chunking for a summary of capacity limits.</p>
Working models	<p>Similar to “schema”, used by Bowlby (1969) to discuss how these help one process their experience of the world.</p>

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APPENDIX A: Research Consent Form

Usability Research Study

UNIVERSITY OF WASHINGTON

CONSENT FORM

Title of Study: WorkSpaces Interface Usability Study

Researcher: Kari Guwaldson Swanson, Ph.D. Candidate
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Researchers' statement

I am asking you to be in a research study. The purpose of this consent form is to give you the information you will need to help you decide whether to be in the study or not. Please read the form carefully. You may use the email address above to ask me questions about the purpose of the research, what I will ask you to do, the possible risks and benefits, your rights as a volunteer, and anything else about the research or this form that is not clear. When I have answered all your questions, you can decide if you want to be in the study or not. This process is called 'informed consent.' You may save or print a copy of this form for your records.

PURPOSE OF THE STUDY

The purpose of this study is to explore how people move around in unfamiliar places. This can help find ways to design that make it easier for users of complex computer applications. The first questionnaire will help decide whether these changes depend on user characteristics.

STUDY PROCEDURES

You may use any computer you wish that can run the research program. It requires a Silverlight-compatible browser. You can use operating system Windows XP and newer Windows operating systems. You can use also use an Intel-based Macintosh with either Firefox 3 or Safari 3/4 browsers.

If you choose to participate, you must click on the checkbox at the bottom of this form. This action will automatically open the research program. The program has all the materials you will need for this study. The program sends all the data to a single file on a secure server. If you sign this form, the program will create a unique, sequentially numbered ID number for you. The ID links your data together. It cannot be used to identify you personally. The program saves no other data on your computer and will delete the cookie when you exit the application.



The program you will use is ISD WorkSpaces. This is a tool to design and manage lessons for large training programs. When you open the program, you will see the Notebook. The Notebook is an addition to the program that has all the information and materials you will need to do this study. It has a copy of this consent form that you can review at any time.

First, you will answer general questions about your age range, job experience, and computer preferences. This information will help me understand what characteristics may be important. It does not include sensitive questions or questions that can identify you specifically. Then you will take a Knowledge survey so I can see whether your previous knowledge and experience change how you use the program. The computer uses your answers to assign you to one of three versions of the program.

You can take a few minutes to explore the program on your own. Instructions will point out important features that will help you operate the program. When you are ready, you will open the Notebook again to see instructions for 20 tasks. You will take the role of a person who designs training materials for an airline. You will review data for a new aircraft system to see how much work your predecessor finished before he quit.

For me to use the results, all survey answers are necessary. Also, you must make it through all tasks; using the Skip Task button DOES count! Most importantly, you must answer the final surveys. You can choose to continue or quit the study. I hope you will always continue.

The Notebook will open to the Progress and Comments pages each time you finish a task. After each task, you can enter comments about your experience. When you finish the tasks, you will take two final surveys about your experience.

You will do each part of the study in the order you see on the Progress page. Once you finish a task, you cannot return to it. During a task, you can go to instructions for that task or other Notebook pages as often as you want. When all tasks are finished, the Notebook will open a final page. This will tell you more about the study and when you can see the results.

RISKS, STRESS, OR DISCOMFORT

The tasks and words in the program will be unfamiliar to most participants so guesses are expected and intended. There are no right or wrong answers, just different ways of doing things. If you are unsure about any answer or action, please just GUESS and keep trying.

If you feel frustrated, slow down, take a break. It can feel difficult when you are trying to work in an unfamiliar environment. If you are feeling stressed, you may take a break or withdraw from the study at any time.

You can do the tasks in this study at your own speed. Speed is not a critical factor but you should stay focused. The computer program will keep track of where you go and what you do in the program but there is NO single, correct way to do the tasks.

You may choose the most comfortable place and time to take part in this study. During the study you should stand up, stretch, and get a drink at regular intervals. There is no time limit except that I ask you to complete the study on the same day you begin. You can only participate one time. This will help keep each participant's experience more similar. If you exit your web browser before you finish, you cannot re-enter the study. You may take as many breaks as you wish as long as the program remains active and the browser open.

BENEFITS OF THE STUDY

This study will provide information about how to better design applications that require complex tasks to be performed, such as those often used on the job.

OTHER INFORMATION

All results will be anonymous. The database will assign each user an ID number. I will see only that number. I will not know who has taken part. I will not be able to identify results with a particular person. All data will remain confidential. Only I or those directly helping me will have access to the unprocessed data. The data may be kept for up to 10 years for more analysis. Results may be published.

Taking part in this study is voluntary. I have no financial support for this study so I can offer no payment for your time and effort. I will, however, very much appreciate your help.

Kari Gunvaldson Swanson
Printed name of researcher


Signature of researcher

15 September 2010
Date

Subject's statement

I verify that I am 18 years of age or older. This study has been explained to me. I volunteer to take part in this research. I have had a chance to ask questions. If I have questions later about the research, I can ask the researcher listed above. If I have questions about my rights as a research subject, I can call the Human Subjects Division at (206) 543-0098. I can print a copy of this consent form or save it to a file.

Check this box to indicate your informed consent to participate in this study.

If you do not want to participate, you can exit by closing your browser window.

APPENDIX B: Human Subjects Review Board Approval

UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON 98105-6613

*Human Subjects Division
Office of Research*

Date: 9/28/2010

PI: Ms. Kari Gunvaldson Swanson

CC: Dr. John Bransford

Re: Human Subjects Certificate of Exemption #39312, "Workspaces Interface Usability Study"

Dear Ms. Gunvaldson Swanson,

This project was submitted for Minimal Risk review, but was determined to be eligible for Certification of Exemption review. The application was transferred from expedited review to exempt review.

We have approved the project under Certification of Exemption category number:

- (1) Educational Research Conducted in Educational Settings
- (2) Survey/Interview/Observation Research
- (3) Survey/Interview Research not Exempted in (2) Above
- (4) Secondary Use of Existing Data
- (5) Evaluation and Demonstration Projects of Federal Programs
- (6) Taste and Food Quality Studies

Period of approval: From 9/28/2010 to 9/27/2015

The following restrictions apply:

1. No changes may be made to the protocol. Should the PI find the need to make revisions, a new Certification of Exemption or Minimal Risk application will be submitted for review and approval.
2. The administrative approval for this activity cannot be renewed. Should the activity need to continue past the approval period, a new Certification of Exemption or Minimal Risk application will be submitted for review and approval.

If you have further questions or concerns, feel free to contact me.

Best regards,
Blair Maman

Human Subjects Review Coordinator
Minimal Risk Review
(206) 543-0919
uwvibro@u.washington.edu
<http://www.washington.edu/research/hsd>

APPENDIX C: Background Questionnaire

Background Questionnaire

The following questions ask about general characteristics that may have an effect on how different groups of people use this program. This information is also used to assign you to one of six experimental groups using three programs. It should only take a couple of minutes to complete. There are NO right or wrong answers. It is important to answer all questions. No personally identifiable information is collected; the answers cannot be traced to a specific individual.

What is your sex?

Female
 Male

What is your age in years?

18-25
 26-40
 41-55
 56-65
 66 years or more

What is your primary language?

English
 Other

What computer operating system are you using for this study?

Windows
 Macintosh or other Apple product
 Linux
 Other

What browser are you using to access this website?

Internet Explorer (Microsoft)
 Firefox (Mozilla)
 Safari (Apple)
 Chrome or Chromium (Google)
 Opera (Opera Software)
 Other

How many years have you used a computer?

Less than 4 years
 4-10 years
 More than 10 years

What ways of learning something for the first time do you usually prefer?

on (circle) is a scale from the idea on the left to the idea on the middle rating indicates an equal combination of both. Choose one

Text Pictures

Listening Reading

Expert Do it myself

Look up an answer Ask someone

Step-by-step instructions Unguided exploration

Missing Answers!

Please make sure you answer all questions before you continue.

OK

Background Questionnaire - 2

What is the highest degree or level of school you have completed?

If currently enrolled, mark the previous grade or highest degree received.

High school diploma or less
 Associate degree (for example: AA, AS)
 Technical or vocational certificate
 Bachelor's degree (for example: BA, AB, BS, BEd)
 Master's Degree (MA, MS, MEng, MEd, MSW, MBA)
 Professional degree (for example: MD, DDS, DVM, LLB, JD)
 Doctoral degree (for example: PhD, EdD)

What types of job(s) have you worked at *for at least 1 year* ?

Include ALL types of job skills, even if you are not currently working in that area. Skip all that do not apply. Select all job types that apply. Rate your level of expertise for each selected job.

Education-related experience

Teacher (K-12, college, medical, school, etc.)
Novice Expert

Training instructor (vocational, consulting, etc.)
Novice Expert

Physical Trainer (for example: sports, dance, health)
Novice Expert

Education/Training system administrator or support person
Novice Expert

Education-related experience, continued

Designer or developer of curricula or instructional materials (for example: workbooks, training manuals, CBT/CBI, videos, instructional games and activities, etc.)
Novice Expert

Other education-related (Enter type and rate your experience)
Type:
Novice Expert

Aviation-related experience

Aircraft Maintenance, Pilot/Flight Crew, or Air traffic control
Novice Expert

Aviation support personnel (for example: reservation agents)
Novice Expert

Other Aircraft-related
Type:
Novice Expert

Other experience

Homemaker
Novice Expert

Visual Designer (for example: architecture, art/graphics, website, video, film, animation)
Novice Expert

Background Questionnaire - 3

What types of job(s) have you worked at *for at least 1 year*?

Other experience, continued

- Skilled Labor - Trades
Novice ○●●●● Expert
- Engineer (not software-related)
Novice ○●●●● Expert
- Systems Design or Development (for example: hardware environments, infrastructure supports, software applications, databases, manufacturing processes, etc.)
Novice ○●●●● Expert
- Analyst (for example: one who performs analyses of usability, needs/gaps, requirements, cost-benefits, financial data, trends, job tasks, or similar)
Novice ○●●●● Expert
- Records manager, analyst, or clerk, (for example: data entry, accountant, inventory, personnel, configuration or change management, etc.)
Novice ○●●●● Expert
- Retail and sales (for example: Business owner, salesperson, clerk, buyer)
Novice ○●●●● Expert
- Other job experience
Type:
Novice ○●●●● Expert
- No work experience

Please rate the following statements by checking a circle on each scale to indicate your level of agreement.

I want to get a lot of information about a new activity before I start to do it.

For example, driving to a new location, planning a foreign trip, trying out a new application, or putting together a kit.

False ○●●●● True

I am familiar with airplane-related terminology and activities.

False ○●●●● True

I mostly use a computer for email or writing documents.

False ○●●●● True

I play complex games on a computer or game console (for example: World of Warcraft, Civilization, The Sims, Counter-Strike, Sim City, Diablo)

False ○●●●● True

At school or work I have used a computer almost every day.

False ○●●●● True

As a computer user, I consider my overall proficiency to be:

Novice ○●●●● Expert

A good-looking application is important to me.

Not important ○●●●● Very important



Background Questionnaire - 4

Please rate the following statements by checking a circle on each scale to indicate your level of agreement.

An application I use for my job must be easy to use.

Not important ●○●○●○ Very important

I find it difficult to read or interpret maps and diagrams.

Rarely ●○●○●○ Often

I need to know *why* I do the tasks, not just *how* to do them:

Never ●○●○●○ Always

I often feel lost when browsing the Internet/Web

False ●○●○●○ True

I use one or more computer applications at work to do my primary job.

False ●○●○●○ True
○ Not applicable

I have used a computer-based flight simulator.

Never ●○●○●○ Often

I am relaxed most of the time.

False ●○●○●○ True

I have difficulty understanding abstract ideas.

False ●○●○●○ True

I spend time reflecting on things.

False ●○●○●○ True



You have completed the Background Questionnaire!

You're doing great! Your answers will now be used to assign you to one of three programs.

You have one more set-up task to do (the Knowledge Check) before you begin the experimental part of this study.

When you click the NEXT button, the program will assign you to the version you will use for the rest of the Study. Please be patient.



APPENDIX D: Instructional Experience Calculation

The sum of values provides a score for exposure to instructional methods.

QNr	QText	Code	Response	Value
8	What is the highest degree or level of school you have completed?	Q8_1	High school diploma or less	0
		Q8_2	Associate degree (for example: AA, AS)	0
		Q8_3	Technical or vocational certificate	0
		Q8_4	Bachelor's degree (for example: BA, AB, BS, BEd)	1
		Q8_5	Master's Degree (for example: MA, MS, MEng, MEd, MSW, MBA)	3
		Q8_6	Professional degree (for example: MD, DDS, DVM, LLB, JD)	5
		Q8_7	Doctoral degree (for example: PhD, EdD)	5
9	K-12 teacher, college/university, medical or law school, etc. professor/instructor	Q9_1	Novice (1) - Expert (5)	10
		Q9_2		12
		Q9_3		14
		Q9_4		15
		Q9_5		18
10	Training instructor (for example: vocational, corporate training, consulting)	Q10_1	Novice (1) - Expert (5)	5
		Q10_2		6
		Q10_3		7
		Q10_4		8
		Q10_5		9
11	Coach, Physical Trainer (for example: sports, dance, health/personal)	Q11_1	Novice (1) - Expert (5)	0
		Q11_2		0
		Q11_3		1
		Q11_4		2
		Q11_5		3
12	Education or Training system administrator, manager, or other support person	Q12_1	Novice (1) - Expert (5)	5
		Q12_2		6
		Q12_3		8
		Q12_4		10
		Q12_5		12
13	Designer or	Q13_1		10

QNr	QText	Code	Response	Value
	developer of curricula or instructional materials	Q13_2	Novice (1) - Expert (5)	12
		Q13_3		15
		Q13_4		18
		Q13_5		20
14	Other education- related occupation	Q14_1	Novice (1) - Expert (5)	5
		Q14_2		6
		Q14_3		7
		Q14_4		8
		Q14_5		9

APPENDIX E: Pre-test

This version was used for the WEB and MAP versions. The Post-test does not include the aircraft-related questions but is otherwise the same as the Pre-test.

Knowledge Check 1

Answer all questions as quickly as possible. **Guess!** You aren't expected to know many of the answers. Use your first impression. Please don't skip any questions.

Note: MENU OPTION refers to a button, tab, or hyperlink that takes you to another page where you can find information or do a job.

You are listing the steps the mechanic must follow to service the nose gear. What menu option would you select?

- Courseware Design
- Needs Analysis
- Task Analysis

What word or phrase is most directly related to a Knowledge Objective?

- Test objective
- A skill
- A topic outline

What word or phrase most belongs to this group of words? Topic Outline, Lesson Design Review, Storyboard

- Course Evaluation
- Media Tracking
- Audio Request

What word or phrase is a part or subdivision of a courseware production process?

- Process management
- Media library
- Equipment

You are developing a lesson about how to install components for a new radio system. Which activity in this group would you do first?

- Write learning objectives
- Identify related skills
- Identify all the new components

What does Effectivity mean?


- Having an intended effect or outcome
- Applicable to a specific use
- How well a product functions

You want to look up what failures are associated with a Weather system test. What menu option will you select?

- Task Analysis
- Component Analysis
- Maintenance

What word or phrase is most directly related to a physical performance objective?

- A skill
- A task
- A test objective



Knowledge Check 2

What word or phrase most belongs to this group of words? Status, Track Media, Integrate

- Template
- Software User Guide
- Prerequisites

What word or phrase is a type of shared data?

- Design Review
- System
- Lesson

What job must you finish before you analyze a subtask?

- Plan the curriculum
- Write learning objectives
- Define a task hierarchy

The term used for establishing a relationship between two ideas is:

- link
- connection
- assignment

Which component is part of the Weather Radar Control Panel?

- ND mode selector
- TERR OVRD switch
- GAIN control

You want to specify how you will test a learner's understanding of the purpose of the WX Radar System / EFIS System. What main menu option would you select?

- Learning Analysis
- Maintenance
- Objectives

What word or phrase most belongs to this group of words? Prerequisites, Lesson Goals, Group Objectives

- Course Schedule
- Skills-Knowledge Assignments
- Media Requests


What word or phrase most belongs to this group of words? Components, Facilities, Roles

- Change Drivers
- Learning Objectives
- Topic Outline

What word or phrase is most closely related to a list of workplace jobs or tasks?

- Prerequisites
- Skill objectives
- DIF Analysis

Remember: Do NOT use the browser back arrow to go to previous pages!



Knowledge Check 3

You are developing the first lesson on the Navigation system. Which activity in this group would you do first?

- Define testing criteria
- Write a lesson plan
- Define the lesson structure

Templates are most often used for:

- workplace job analysis
- media assignments
- learning objectives

What word or phrase is most directly related to a task?

- A test objective
- A skill
- A system

What word or phrase most belongs to this group of words?
Performer, Standard, Fact

- Condition
- Purpose
- Consequences

What word or phrase is a *part* of a course?

- Curriculum
- A module
- Lesson unit

You want to select the resources the student needs to have available during a test on the Weather Radar. What menu option would you select?

- Maintenance
- Learning Analysis
- Task Analysis

What job must you finish before you can write a test objective ?

- Plan the curriculum
- Identify related skills
- Assign objectives to media

What is a subtask?

- The lowest level in a hierarchical list of jobs
- A generic procedure
- A trained skill or activity

What provides on-ground electrical power to the aircraft?

- The engines
- The bus-transfer system
- The APU

Remember: Answer or guess quickly and do NOT use the browser back arrow to go to previous pages!



Knowledge Check - 4

What word or phrase is most directly related to a subtask?

- Effectivity
- Component Analysis
- DIF Analysis

What word or phrase most belongs to this group of words?

Problem-solving, Concepts, Facts

- Rules
- Memory
- Reason

What word or phrase is most directly related to a topic?

- A unit
- A storyboard
- A module

You are thinking about how you should present lesson content. What menu option will you select to find whether a computer simulation of the CDU is available to use?

- Courseware Design
- Learning Analysis
- Maintenance

You are developing a lesson on how to test the Ground Proximity system. Which activity in this group would you do first?

- Identify related facts
- Identify motivational factors
- Identify related physical performance goals

The term for resource information used to create new data or to connect more detail about other items is called:

- support information
- shared data
- baseline information

What components transfer fuel between the tanks?

- Defuelers
- Boost pumps
- Sump valves

What word or phrase is a part of or subdivision of a lesson specification?

- Components
- Primary Media
- Support equipment

Remember: Answer or guess quickly and do NOT use the browser back arrow to go to previous pages!



Knowledge Check 5

What word or phrase most belongs to this group of words?
Subtask, Failures, Importance

- Reports
- DIF Analysis
- Media

What word or phrase is most directly related to Production?

- Media tracking
- Task hierarchy
- Storyboard

You are creating a hierarchical list of aircraft systems and their components. What menu item would you select?

- Task Analysis
- Component analysis
- Maintenance

You are developing the first lesson on how to use ISD WorkSpaces. Which activity in this group will you do first?

- Write a topic outline
- Create a storyboard
- Specify lesson resources

What is an assignment?

- An association between two types of data
- A learning task
- A specification

What is the primary function of the nose gear?

- Landing
- Take-off control
- Steering

What word or phrase is most directly related to 'system'?

- A component
- A lower level task
- A skill objective

What word or phrase most belongs to this group of words?
Safety, Situation Awareness, Time Critical

- Consequences
- Difficulty
- Effectivity

What word or phrase is most directly related to 'unit'?

- A curriculum
- A course
- A module

You need to check whether a graphic you have requested is available now. What menu option would you select?

- Production
- Courseware Design
- Maintenance



Knowledge Check 6

What job must you finish before you can release a lesson specification?

- Plan the curriculum
- Identify related publications
- Assign objectives to media

You are associating information about two system failures with a procedure. You are analyzing a:

- publication
- component
- subtask

When are the automatic spoilers extended?

- In case of flap failure
- When the aircraft speed exceeds 60 knots
- When the reverse thrust lever is raised

You need to add a new section to the GPWS lesson. What menu option would you select?

- Curriculum Planning
- Organize Courses
- Production

What word or phrase is most directly related to a list of physical activities you must be able to do on the job?

- A skill objective
- A system
- A subtask

You want to find out whether a lesson is going to be presented as a lecture or simulator session. What main menu option would you select?

- Media Analysis
- Production
- Curriculum Planning

You need to write a development plan for the GPS lesson and want to use the Systems template. What menu option would you select to open that template?

- Courseware Design
- Maintenance
- Curriculum Planning

What is a 'unit'?

- A set of related lessons
- A lesson section
- A set of courses

The term for information used to describe a performance situation, condition, or context is called:

- a cue
- a subtask
- a scenario



Knowledge Check 7

What word or phrase is most directly related to a test objective?

- A task
- A skill
- A lesson

You are developing the first lesson on how to replace the GPS antenna. Which activity in this group would you do first?

- Write learning objectives
- List component resources
- Define the curriculum elements

What is a skill?

- The ability to use one's knowledge effectively
- A developed aptitude or ability
- A learned physical activity

What is a change driver?

- A program that controls how changes are made
- The reason for making for a change
- The person requesting a change

Knowledge objectives are best used to describe learning goals for:

- both mental and physical abilities
- factual and problem-solving information
- component operation

The term for materials developed to guide or present a lesson is:

- instruction
- courseware
- lesson materials

What is a macro?

- A rule about how to map an input to an output
- Equipment or panel with control components
- A series of commands done by a single keystroke

The term that indicates which type of program, aircraft, or courses that data can be used in is called:

- effectivity
- applicability
- validity

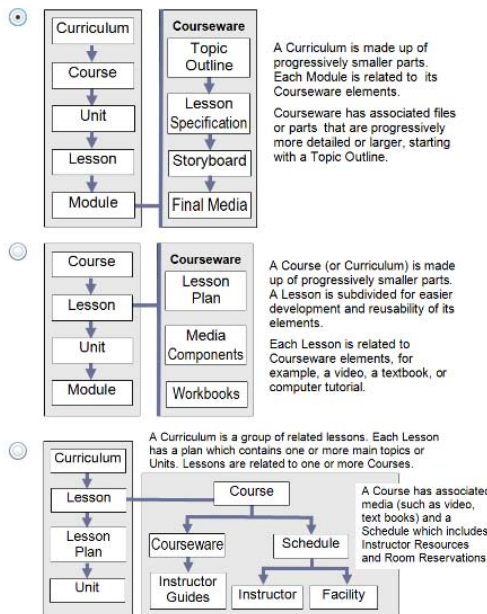
Select the sequence that shows the order you would do these tasks when starting a new set of lessons.

- 1. Define course structure;
2. Identify tasks
3. Perform DIF Analysis.
- 1. Write objectives;
2. Define course structure;
3. Write a topic outline.
- 1. Write objectives;
2. Identify new components;
3. Define course structure.

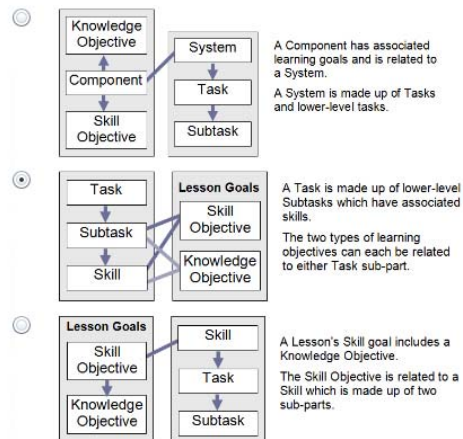


Knowledge Check 8

Select the diagram that most accurately shows the relationships between these data items.



Select the diagram that most accurately shows the relationships between these data items.



Congratulations! You completed this Knowledge Check.



APPENDIX F: Task Instructions

Task instruction pages in the Notebook provide a scenario as context for the job, an explanation of the target data location, and optional Hints. Their purpose is to encourage exposure to selected pages. The COPY TEXT button omits the scenario and the target text. The latter remains available on hover over the Notebook without the need to re-open. This text combines navigation and hints but is more explicit. There are slight differences between the wording for each of the treatments. The MAP version is shown.

Task 1

From the menu select in order: Maintenance/ Manage Shared Data/Component List.
Set Effectivity to 767.
Select switch from Component dropdown.
Click SHOW button.
Click Component name in list.

Task 2

From the menu select in order: Maintenance/ Manage Shared Data/ Skill Info.
Select 'Misc. Keywords' as Category.
Select keyword 'Turn on/off' in the next box.
Click SEARCH button.
Select Skill/Activity in results list.

Task 3

From the menu select in order: Task Analysis/ Build Task List.
Select from each dropdown: 1 Maintenance Duties, 2 Navigation System Procedures, 3 System Tests, 4 Integrated WXR/Windshear System Operational Test.
Click in Task Comments.

Task 4

From the menu select in order: Task Analysis/ Analyze Subtasks.
Look at both WXR/Windshear Tests. Compare Calculated Results.
Choose Test with highest score.
Click in Developer Decision.

Task 5

From the menu select in order: Task Analysis/ Assign Skills.
Select Subtask.
Scroll down list of Skill Assignments.
Click on skill name.

Task 6

From the menu select in order: Learning Analysis/ Add/Edit Skill Objectives.

Change selection to correct Subtask.
Click on its Assigned Cue below.

Task 7

From the menu select in order: Learning Analysis/ Add/Edit Knowledge Objectives.
Select switch name in Component dropdown.
Click SEARCH button.
Select Knowledge statement in results list.

Task 8

From the menu select in order: Learning Analysis/ Link Skills to Knowledge.
Enter Skill ID 273 in Search panel. Click SHOW.
In 'Select Knowledge Objective' search panel select switch name in Component dropdown. Click SEARCH button.
Select activity/skill from Options.
Click on the ASSIGN button.

Task 9

From the menu select in order: Curriculum Planning/ Define Curriculum.
Select from each dropdown: Maintenance Training - 767, 767MTP - 767 Maintenance Procedures, Navigation System, 767 WXR and Windshear System - Introduction, Module: F.
Click EDIT.
Click on Module Purpose.

Task 10

From the menu select in order: Courseware Design/ Add/Edit Topic Outline.
Select Course: 767 Maintenance Procedures, Unit: Navigation System Lesson: 767 WXR/Windshear Sys Intro, Module: B.
Scroll through topics to click on 'Dummy loads'.

Task 11

From the menu select in order: Courseware Design, Prepare Lesson Plan.
Do not change course/lesson selections.
Click in 'Spec Status' dropdown.

Task 12

From the menu select in order: Learning Analysis/ Add/Edit Knowledge Objectives.
Click ADD button (Page bottom).
1. Enter Keyword 'History'.
2. Select template from dropdown.
6. Click in Cognitive Effort dropdown.

Task 13

From the menu select in order: Task Analysis/ Build Task List.
Change Task (Level 4) dropdown to: 'Windshear Calibration Procedure'.
Locate task in list below.
Click in empty 'Is Subtask?' checkbox.

Task 14

From the menu select in order: Maintenance, Manage Shared Data/ Learning Objective. Cues, Conditions, Standards.
Click REQ (Request) button next to list of Learning Objective Conditions.

Task 15

From the menu select in order: Courseware Design/ Add/Edit Topic Outline.
Select Course: 767 Maintenance Procedures, Lesson: Traffic Collision Avoidance System (TCAS) - Intro, Module: B.
Click in Outline Format dropdown.

Task 16

From the menu select in order: Task Analysis/- Analyze Subtasks.
Select any subtask.
Click the 'DIF Definitions' button.
Review definitions, then CLOSE.

Task 17

From the menu select in order: Courseware Design/ Add/Edit Topic Outline.
Select Course: 767 Maintenance Procedures, Unit: Navigation System, Lesson: 767 WXR/Windshear Sys Intro, Module: F.
Click on topic 'Circuit breakers closed'.
Select target Knowledge Objective in dropdown.
Click ASSIGN button.

Task 18

From the menu select in order: Maintenance/- Manage Shared Data/ Skill Info.
Select 'Radome' from Component LOCATION dropdown.
Click SEARCH button.
Select Skill/Activity in results list.
Click MORE button at bottom of page. Look for 'Assigned Components' list.
Click Component name.

Task 19

From the menu select in order: Learning Analysis/ Add/Edit Knowledge Objectives
Select switch from Component dropdown.
Click SEARCH button.
Select target Knowledge Objective.
Click MORE button.
Click in box 'Based on this Template'.

Task 20

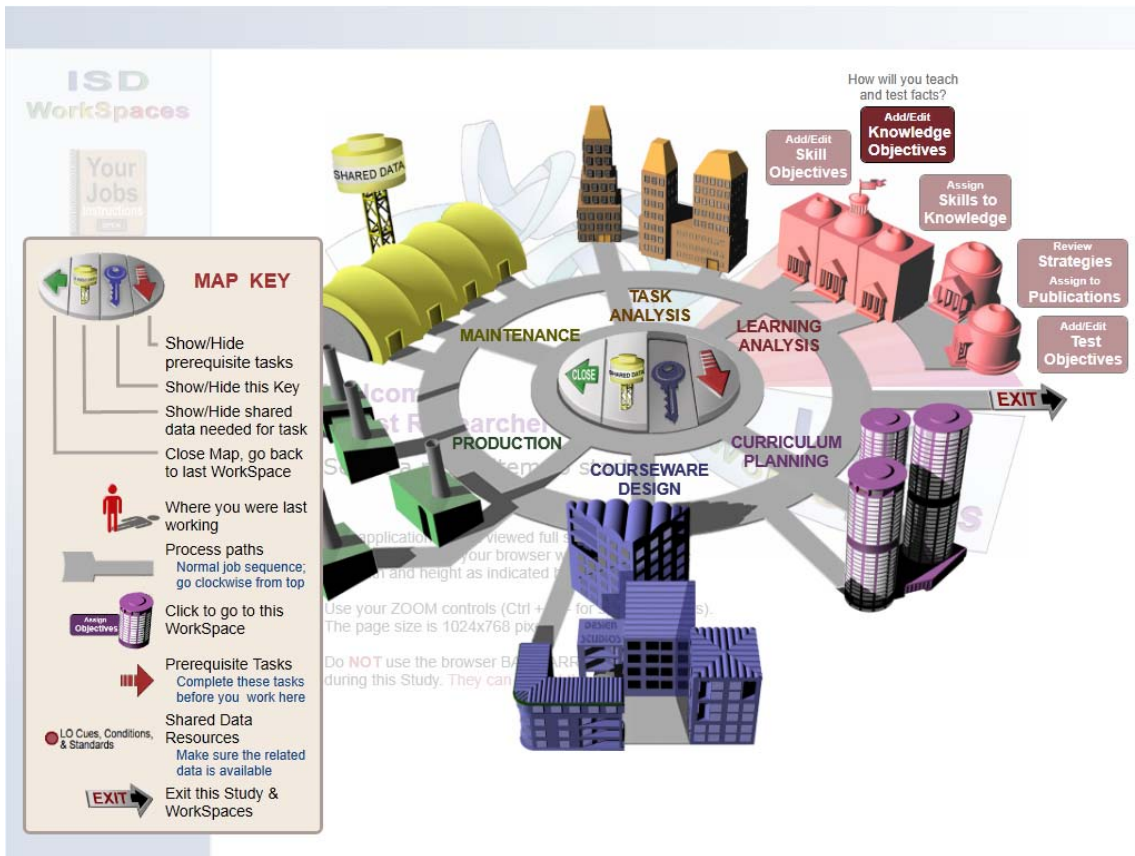
From the menu select in order: Learning Analysis/ Add/Edit Skill Objectives
Select correct Subtask.
Select 'Standard' from CCS Type dropdown.
Enter keyword 'efficient'.
Click SEARCH button.
Select target data from Options dropdown.

APPENDIX G: Task Data

<i>Task</i>	<i># People</i>	<i>Nr Timeouts</i>	<i>% Timeouts</i>	<i>Expert Time</i>	<i>Avg Time</i>
1	113	88	77.9%	0.69	6.9
2	103	74	71.8%	0.81	6.4
3	95	62	65.3%	0.48	5.9
4	91	46	50.5%	0.17	4.8
5	88	37	42.0%	0.25	4.2
6	86	47	54.7%	0.21	4.7
7	82	42	51.2%	0.74	4.7
8	77	54	70.1%	0.77	6.3
9	75	44	58.7%	0.38	5.6
10	72	34	47.2%	0.47	4.7
11	70	13	18.6%	0.17	2.2
12	70	38	54.3%	0.45	5.5
13	69	33	47.8%	0.44	4.8
14	69	25	36.2%	0.19	3.9
15	67	24	35.8%	0.37	4.1
16	67	9	13.4%	0.41	2.3
17	67	34	50.7%	0.70	5.3
18	67	37	55.2%	0.83	5.1
19	67	22	32.8%	0.86	4.4
20	65	26	40.0%	0.51	3.9

The above table shows average times for all people who completed each task. Timeouts (tasks exceeding 5 minutes) increase substantially when looking at the numbers for those who completed no more than the listed task. For example, of the 113 completing task one, ten quit after that task and all exceeded five minutes. Another eight quit after timing out on task two. Of those that completed less than eight tasks, nearly all timed out on every task. This supports the assumption that drop-out rates were affected by perceived difficulty.

APPENDIX H: MAP Menu Resource Information



Control buttons in the Map center close the menu and control the amount of supplemental information shown when open. This view shows only the Map Key button selected. When the mouse is located over a main menu item, such as Learning Analysis above, page labels show and the background highlight reinforces which pages are part of that process. When the mouse hovers over a specific page, an explanation of page function appears. If either the Shared Data button or Prerequisite button is depressed, that additional information will show for the selected page. An image of the selected page building shows below the Notebook button when the menu is closed, acting as a breadcrumb. However, breadcrumb navigation is not implemented for this study.

APPENDIX I: Usability Survey

This screenshot is an example of the survey style used. The full text follows.

The screenshot shows a two-page survey form. The left page is titled "Usability Survey 1" and contains an introductory paragraph and a "General Impression" section with five Likert scales. The right page is titled "Screen Design" and contains seven Likert scales. A "NEXT" button is located at the bottom right of the right page.

Usability Survey 1

Please rate the following features by checking a circle on each scale to indicate your level of agreement. The purpose of this survey is to better understand how easy or difficult your version of the application has been for you to use. It should only take a couple of minutes to complete. There are no right or wrong answers. Do not skip any questions.

General Impression

I found the use of this application to be:

Terrible Wonderful

Frustrating Satisfying

Dull Stimulating

Difficult Easy

Confusing Clear

Screen Design

I thought the overall look of the pages was:

Terrible Wonderful

I found the use of color:

Unhelpful Helpful

The organization of screen elements (layout) was:

Unhelpful Helpful

I found the text and fonts on the computer screen:

Hard To read Easy to read

The amount of information on each screen was:

Too much Too little

I thought the arrangement of information on screen was:

Not logical Logical

I found the sequence of screens:

Confusing Clear

NEXT

Please rate the following features by checking a circle on each scale to indicate your level of agreement.

The purpose of this survey is to better understand how easy or difficult this application has been for you to use. It should only take a couple of minutes to complete. There are no right or wrong answers. Do not skip any questions.

General Impression

I found the use of this application to be:

- Terrible Wonderful
- Frustrating Satisfying
- Dull Stimulating
- Difficult Easy
- Confusing Clear

Page Design

I thought the overall look of the pages was:

- Terrible Wonderful
- I found the use of color:
Unhelpful Helpful
- The layout or organization of the pages was:
Unhelpful Helpful
- I found the text and fonts on the computer screen:
Hard To read Easy to read
- The amount of information on each screen was:
Too much Too little
- I thought the arrangement of information on page was:
Not logical Logical
- I found the sequence of pages:
Confusing Clear

Vocabulary

- I found the use of vocabulary was overall:
Inconsistent Consistent
- I thought the Find-It task instructions in the Notebook were:
Confusing Clear
- I found the interpretation of names of menu or navigation choices to be:
Difficult Easy
- I thought button labels and page directions were overall:
Confusing Clear

Use

- I found the computer setup/preparation for the study was:
Difficult Easy
- I thought learning to use the application was:
Difficult Easy
- I thought the time to learn to use the application was:
Slow Fast
- I found the exploration of features by trial and error to be:
Discouraging Encouraging
- I found that when I clicked on an item, the result was:
Unpredictable Predictable
- I thought the organization of the Navigation menus was:
Unhelpful Helpful
- I thought use of menu or navigation options was:
Difficult Easy
- I thought the Notebook Progress page was:
Unhelpful Helpful
- I thought the instructions (in the Notebook) were:
Unclear Clear
- I was able to do the 20 experimental tasks (the information searches):
With Difficulty Easily

- I thought the steps to complete a task followed a sequence that was:
Not logical Logical
- I could tell when the computer responded to my actions:
Never Always
- I could find my way around the application:
With Difficulty Easily
- By the end I felt I knew what I was supposed to do next:
Never Always
- I thought the instructional design process followed in this application was:
Unclear Clear

The navigation controls are the menu items that you use to move between pages.

What did you like *most* about the menu version you used?

[Free text comments]

What did you like *least* about the menu version you used?

[Free text comments]

APPENDIX J: Related Navigation Interface Examples

Traditional Application examples



The marketing for concept mapping software iMindMap touts its uses for a broad array of applications but does not use its precepts in its own application. It employs a traditional horizontal menu bar plus the usual graphical task bar. (Buzan, 2010)

Web Examples



This example of an informational website (<http://www.informs.org/Find-Research-Publications/INFORMS-Librarians-Portal>, downloaded 2010) has 5 different navigation control sets on a single screen using horizontal tabbed menus with and without graphics and vertical lists. D is the only group showing an attempt at explicit categorization. Although it is likely that the designer had an organizing principle in mind, the navigation appears to be a random placement of labeled links. The site has since been re-designed but retains the multitude of navigation options.

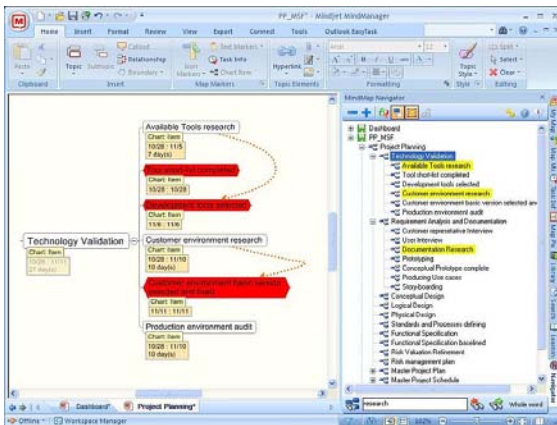
Microsoft IUI test interface



Microsoft (2000) proposed this approach to support a more robust user mental model of the task space: one task per page, explicitly titled – and plenty of white space. It was not generally implemented and is in stark contrast to their more recent, crowded, and perceptually difficult "ribbon" design.

Boeing did use this sparse approach for a training program task analysis database. Users developed no sense of the overall process, had difficulty finding pages to perform specific tasks, but were able to do the limited tasks without difficulty once arriving at the correct page.

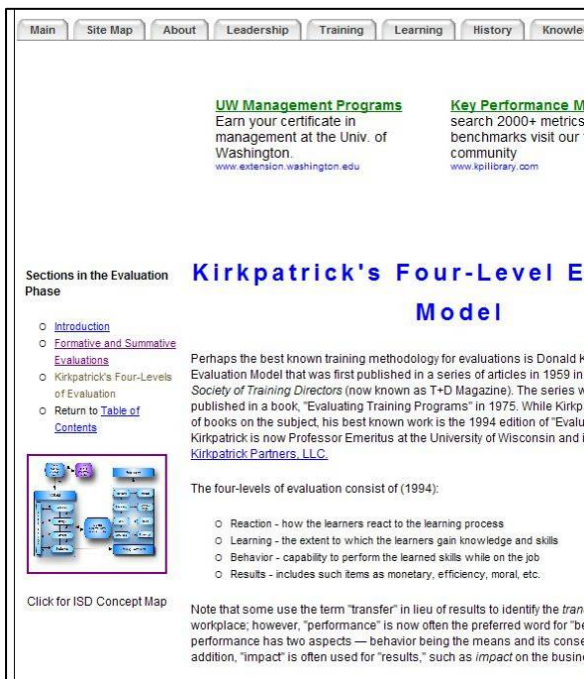
Map-like interface examples



task bar (Buzan, 2010).

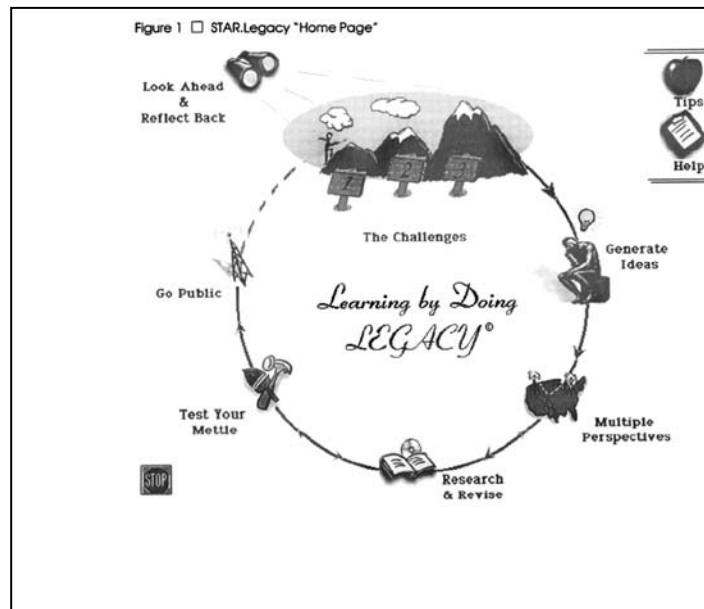
The marketing for concept mapping software iMindMap touts its uses for a broad array of applications but the company appears to not trust the navigational robustness of a map. The map object is supplemented not only by a traditional horizontal menu bar but a hierarchical tree drop-down menu plus the usual graphical

Don Clark's website (<http://www.nwlink.com/~donclark/>) is a rare example of navigation using a concept map – but again duplicated with more traditional menus:



the tabbed choices along the top and a submenu above the map in a vertical column. The concept map is not consistently available throughout the site and the space is not reserved for navigation only. The same location is used for secondary information, images of graphs, and other details.

The STAR.Legacy software (Schwartz et al., 1999) provides an inquiry process model. The Home Page of this application presents the menu as a map of the procedure and shows progress through the cycle of activities. The circle with unidirectional arrows implies a linear route through the process. Images reflect familiar real-world activity analogs to give semantic context and indicate key stages of the cycle.



APPENDIX K: Examples of Inactive Pages

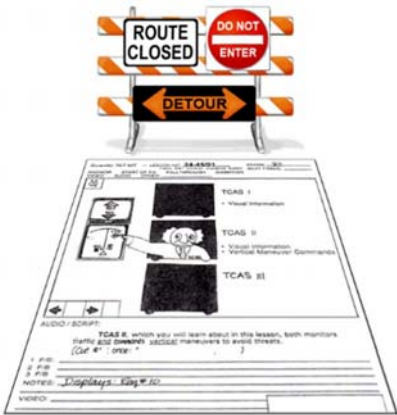
ISD WorkSpaces

Your Jobs Instructions (PDF)

Task Analysis
Learning Analysis
Curriculum Planning
Courseware Design
Topic Outline
Lesson Specification
Storyboards
Design Reviews
Media Requests
Production
Maintenance
Reports

EXIT WorkSpaces

The Storyboard Development page is not active for this study. Please select another to continue.



A storyboard template with sections for TCAS I, TCAS II, and TCAS III, and an AUDIO SCRIPT section.

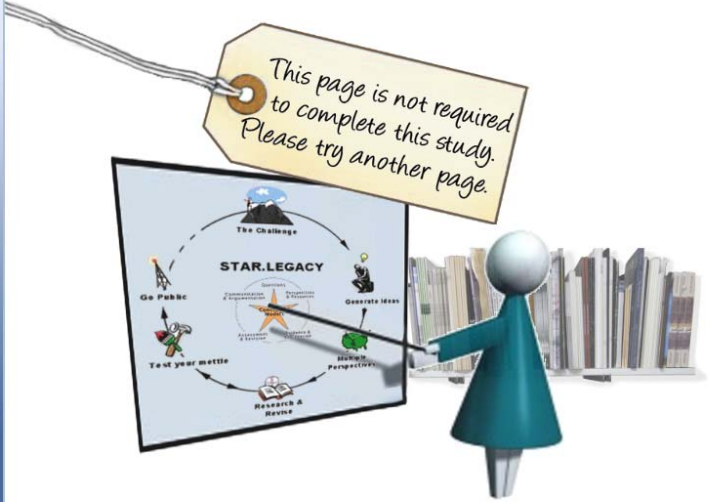
File Edit Analyze Link Admin Reports

ISD WorkSpaces

Your Jobs Instructions (PDF)

Learning Objective Links to Teaching Strategies & Publications

This page is not required to complete this study. Please try another page.



A 3D stick figure pointing to a diagram titled "STAR.LEGACY" which shows a circular flow of steps: The Challenge, Go Public, Test your mettle, Research & Revise, Student Perspectives, Generate Ideas, and Evaluate. A sign above the figure says "This page is not required to complete this study. Please try another page."

VITA

Kari Gunvaldson Swanson was born in Minneapolis, MN. She attended St. Olaf College in Northfield, MN, earning a Bachelor of Arts degree with honors in Spanish, Norwegian, and Southeast Asian Studies, and completed requirements for an Art major. She studied at both Chulalongkorn University in Bangkok, Thailand and the University of Oslo in Norway. She then moved to Seattle, WA. In 1973 she received a Master of Arts in Scandinavian Languages and Literature with a focus on Philology from the University of Washington. In 1990 she received a Master of Education degree in Educational Communications and Technology from the University of Washington College of Education. She worked on and managed computer-based training projects at Boeing for nearly 15 years and directed User Experience at Virtuoso and Expedia. In 2012 she graduated with a Doctor of Philosophy in Human Cognition and Interface Design from the University of Washington.