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THE JOB TASK MODEL AS A MEANS FOR UNDERSTANDING COMPUTER USAGE IN THE WORK PLACE

by

Vicki S. Napper

A dissertation submitted in partial fulfillment of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Education (Instructional Technology)

Approved:

UTAH STATE UNIVERSITY Logan, Utah

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ABSTRACT

The Job Task Model As a Means for Understanding Computer Usage in the Workplace

by

Vicki S. Napper, Doctor of Philosophy Utah State University, 1997

Major Professor: Dr. Byron R. Burnham Department: Instructional Technology

A qualitative study of a workplace was conducted through the use of interviews and observation of ten participants working in hardware and software engineering. The study arose from a lack of information on computer usage in workplace settings and a lack of identified functional needs for skills-based training.

There were three primary guiding questions and areas of findings in this study: I. Does the job task model define the areas of computer literacy for the individual worker?

The job task model proved to be an effective method for analyzing tasks, tools, and the environment for usage of computer technologies in specialized professions.

II. Does the type of job task influence the functional needs for computer usage in the areas of training, hardware and software usage, application of individual anthropometric data, and workstation design?

The job tasks did not influence how the participants were trained in the use of computers. The primary method of learning to use computer hardware and software was through self-instruction. However, the type of job task did influence the type of hardware and software needed to perform a task. Professional employees needed to know how to

use both general and specific types of hardware and software. The job task affected the ergonomic arrangement of work areas, but the participants generally lacked training in how to identify and correct risk factors that may lead to computer-related injury.

III. What are the stress factors in this workplace setting? Do the stress factors influence computer-related injury rates in this workplace and if so, how can those types of injuries be reduced?

The stress factors identified in this setting included job demand factors, psychosocial factors, and ergonomic factors. Although these types of stress factors have been associated with computer-related injury through research, none of the participants reported injury associated with computer usage. It was also found that the participants did not consider musculoskeletal disorders to be injuries but rather illnesses.

Implications of the study suggest that the job task model provides a balanced approach to the design of instructional materials. Further, by allowing one category of the job task model to be dominant in the instructional content also appears to weaken the overall instructional validity.

(258 pages)

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Also I extend my gratitude to those people who took time to read and comment on my research documents. Writing a qualitative study requires time and patience, both of which I have learned to appreciate.

Vicki S. Napper

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CHAPTER 1

AN OVERVIEW OF THE STUDY

Introduction

The eighteenth century was a time of chemical and mechanical discoveries that led to the emergence of the Industrial Age in the nineteenth century. The development of motion pictures, the gramophone, and the discovery of the way to send signals via wires at the end of the nineteenth century led to the Communications Revolution of the twentieth century (Moran 1994).

The end of this century has also been a time of discovery, defined by the transformation of both economic and educational systems as they become part of an information revolution. This transition toward the Information Age began with the development of two new instructional frameworks during World War II. These frameworks were based on communication and system theories that allowed military trainers to transmit knowledge and skills to massive numbers of people in short amounts of time (Association for Educational Communications and Technology 1977).

The merging of communication theories with the systematic development and management of instruction came to be known as instructional technology (IT) (ibid.). The traditional instructional elements within the IT approach to training include: (1) the message, (2) the materials and devices used to convey the message, (3) the techniques for presenting the message and materials, and (4) the location where instruction takes place (ibid.). Within this framework of instructional elements in IT, the proper use of devices used to deliver training is an important component of the instructional process.

One such instructional device is the computer. However, as personal computing systems have evolved from little more than an electronic typewriter into information appliances, the interaction between computing systems and people has also intensified.

Academic Foundations of Computer Training

Computing systems are complex systems involving the interaction of people and machines to create information products (Booth 1992). People who become competent in the use of these complex systems are said to be computer literate.

In postsecondary education, computer literacy has been developed around training on how to operate a computer to solve problems or to generate information within the area of an academic discipline. These skills are primarily ones that students need to know for achieving academic excellence (Shields 1995) and may or may not meet requirements for performance of job tasks in a workplace setting.

Computer literacy training in the 1980s was based on achieving competency in: (1) activating hardware and using a keyboard, (2) use of simple software, and (3) application of logic skills. Also, achieving a positive attitude toward use of computers was a desirable affective goal of computer literacy training (Amini 1993; Anderson and Collis 1993; Day and Athey 1985; Hofmeister 1984; Martinez and Mead 1988). The requirements for computer literacy have also varied from academic department to academic department. This variance may have been caused by the development of internally supporting technologies or software that did not rely on other academic departments for the overall product of education (Shields 1995). This approach to computer literacy promoted the use of computers for academic goals with little concern for the skills or knowledge needs of the students outside of the department (Pett and Grabiner 1991).

Much of the information on how to set up and use computer keyboards is based on ergonomic research done on the use of typist stations during World War II (Booth 1992). The purpose of that research was to promote efficiency and cut cost. The underlying assumption has been that a computer workstation was just a different kind of typist station that could be used to increase profit through efficiency in motions and cut costs in work settings (Human Factors and Ergonomics Society 1995). Under that assumption, computer literacy instructors guide students to set up their work area like a typist station.

However, the typist station approach to use of computer equipment apparently is inadequate. Increasing evidence has linked incorrect posture and prolonged periods of repetitive motion to injury (Carter and Banister 1994; Pheasant 1991; Scalet 1987). In 1994 alone, 38,336 people in the United States experienced carpal tunnel syndrome injuries that were severe enough to report as worker's compensation claims. These claims amounted to over \$575 million spent for medical care and assistive work devices for sufferers of carpal tunnel syndrome (Fletcher 1990).¹ Carpal tunnel syndrome is the most commonly reported musculoskeletal injury associated with computer-related injury (U. S. Department of Labor 1994; 1995; 1996). It is also suspected that the number of injuries reported is less than those actually experienced by workers (ibid.).

Although health professionals assert that musculoskeletal injuries arising from injury generally occur over a long period of time from accumulating micro-injuries (Atencio 1993; Carter and Banister 1994; Karlo 1996; Pheasant 1991), computerrelated injury has now also become an emerging issue on college campuses for students heavily involved in computer use. In an article published by the Massachusetts Institute of Technology (MIT) student newspaper, injuries such as carpal tunnel syndrome were reported as troublesome across a wide range of academic disciplines (Karlo 1996). In response to an inquiry from this researcher for information on injury rates, an employee at the MIT student health services reported that there were 122 reported computerrelated injuries between July 1996 and June 1997 (Cahill 1997).

¹The figure is derived from the OSHA reported incidence of 38,336 people with carpal tunnel syndrome and the insurance industry estimate of \$15,000 of related payment per case.

David V. Diamond, medical physician at the MIT student health services center, stated:

I think it poses a major—probably the major—risk to students' health. I've seen several hundred people in the last few years; students, staff, faculty - [people] who use computers in large amounts. In terms of injuries, there's nothing else that comes close to what these computers are doing to people at MIT. (Karlo 1996, electronic text)

The new issue for computer literacy training is no longer only what do people need to know about using computers to solve problems or perform tasks, but also what do people need to know about computers to reduce their risk for injury.

Purpose of the Study

Because instructional technology is based on management and development of system components but is lacking in analysis of ergonomic considerations, there is a need to understand the relationships between the job tasks, computer tools, and also the environment where computers are used. This study explored the complex relationship between employees and computers in their workplace setting in order to identify the skills and knowledge needed for safe, efficient work.

A workplace setting was selected for the study rather than an academic setting because the workplace would provide real-life context for understanding the long-term impact of computer use. The study was focused to identify skills and knowledge within the context of actual job tasks.

The study was delimited to exploration of one workplace in order to identify appropriate instructional content during this phase of research. The purpose of this study was to provide data that may be used at a later date to validate instructional content for computer usage training in postsecondary education and that may be used to guide future curriculum development.

Problem Statement

Identification of skills and knowledge as the basis of effective and safe use of computers was the purpose of this study. The areas of exploration for the study were derived primarily from a review of literature that identified the job task model (i.e., tasks, tools, and environment) as a model of workplace activity. The additional inquiry area of stress factors was added to the guiding questions of the study because the review of literature indicated that stress was a factor contributing to computer-related injury. The following are the guiding questions that directed the flow of this study:

- I. Does the job task model define the areas of computer literacy for the individual worker?
 - A. What tasks are generally performed daily? Weekly? Monthly? Other?
 - B. What tools are generally used in performing this job?
 - C. What is the workstation environment for the job tasks?
- II. Does the type of job task influence the functional needs for computer usage in the areas of training, hardware and software usage, application of individual anthropometric data, and workstation design?
 - A. What is the computer usage history of the employees at the workplace?
 - B. What specific training on software and hardware usage is required at a professional level in this workplace?
 - C. What job factors are most important for the participant to understand in designing the configuration of his or her work area?
 - D. What anthropometric and ergonomic factors are most important for the participant to know and apply to individualize his or her work area?
- III. What are the stress factors in this workplace setting?

- A. Do the stress factors influence computer-related injury rates in this workplace?
- B. If there are stress-related injuries, how can those types of injuries be reduced?

Design of the Study

A case study design was used to find the interactions of the job task factors for computer usage in a workplace setting. This study was conducted at a company heavily involved in development of computer software as well as production of computer hardware. The unit of analysis for this study was the job task rather than the individual or organization because the job task guided the work processes and associated skills of the individual workers. Data for the study were collected through interviews, questionnaires, and observation of ten participants. (See Appendix A for the Data Collection Matrix and associated guiding questions.)

Theoretical Orientation of the Study

Qualitative methodology was chosen for this study because a preponderance of reported research related to computer usage indicated a lack of descriptive information on the interaction between the various job task factors arising from workplace conditions. Qualitative research is used to identify and describe how and why phenomena occur (Borg and Gall 1989; Eisner 1991; Fetterman 1989; Merriam 1988; Yin 1989).

The qualitative research method used in this study was based on the methods suggested by Yin (1989) who defines a case study as: (1) an investigation of contemporary phenomena within a real-life context; (2) an inquiry when boundaries

between phenomena and context are not evident; or (3) an inquiry using multiple sources of evidence.

Case study methods provide answers for the proposed research questions through empirical inquiry methods for data collection and analysis. An underlying assumption in this study is that the study data would show divergence between workplace skills and knowledge for computer usage and skills and knowledge for computer usage gained in postsecondary education. Another underlying assumption of the study is that the workplace would influence computer skills and knowledge because the workplace has an economic purpose, goals for continued economic growth, and cultural patterns that influence performance of job tasks.

Importance of the Study

This study investigated actual workplace conditions in a real-life context. Types of interaction between the various job task factors arising from those conditions were identified. The findings of this study provide a framework for validation of the knowledge and skills taught in postsecondary education for the use of computer technologies.

Definition of Terms

The following terms are found in this study. Some of these terms do not have readily agreed upon meaning and additional definitions are provided where appropriate in the study document.

Computer Literacy

Computer literacy is vaguely defined in existing literature and is highly variable depending on the application of the term within its context of usage. A discussion of the term is provided in Chapter 2 in the review of literature. In this study, the term

computer literacy is tied to the traditional skills and knowledge associated with the usage of computer hardware and software and does not include knowledge of risk factors for injury nor information about setting up workstations.

Ergonomics

Ergonomics is a broad term related to the physical and mental interaction between humans and machines. *Ergonomics* in this study is defined as effective usage of computer technology to reduce injury through an understanding of: (1) the dimensions of the human body (anthropometric data), (2) the work area environment where technology is used, and (3) how humans react and interact physically, mentally, and behaviorally with technology. The state of being *ergonomic* indicates a harmony created between human actions and machine actions. The science of *ergonomics* strives to physically fit the machine to the human body and mentally match the task with the capabilities of the worker (Osborne 1982).

Firmware

Firmware is used to indicate the various electronic components, chips, or boards containing multiple electronic components. *Firmware* is a part of the overall product that is called hardware, and hardware is a physically existing object used within a computing system.

Functional Need

"Need" is defined in the educational sense as "a gap between *What Is* and *What Should Be* in terms of results" (Kaufman emphasis, 1982, 73). *Functional need* is therefore identified in this research as the necessary skills and knowledge that are required to perform at a functional level of proficiency in technological settings.

Profession

The term *profession* indicates a type of job performed by a person who has a high degree of specialized training and performs complex tasks of a unique or creative nature (e.g., programmer, system analyst, or engineer). This type of work is characterized by tasks requiring application of specialized knowledge learned through training in a postsecondary institution.

Technology

The term *technology* designates any process applying scientific methods to rationally control people, events, and machines for the solution of problems or practical tasks (Galbraith 1967; Gentry 1991). The term *technology* in this study designates any electronic product used for the solution of logic problems or practical tasks.

Workstation

A *workstation* is defined as a site that is composed of furniture, electronic equipment, and the immediate surrounding environment where job tasks are performed.

Structure of the Dissertation

This dissertation is divided into five chapters. The initial three chapters provide the overview, literature review, and methodology of the study. Chapter 4 presents the findings. Chapter 5 provides conclusions to each guiding question and a discussion of the implications of the findings for future research. Appendices provide documents or data supplemental to the study.

Summary

This study arose from a lack of information on the interaction of tasks, tools, environment, and stress factors about how people used computers in the workplace and the resulting lack of identified necessary skills and knowledge. A case study approach was used to obtain data on the skills and knowledge needed for computer usage in the areas related to the job task model (i.e., task, tool, and environment)² and the area of stress factors related to injury.

The guiding questions for this study were (1) Does the job task model define the areas of computer literacy for the individual worker; (2) Does the type of job task influence the functional needs for computer usage in the areas of training, hardware and software usage, individual anthropometric data, and workstation design; and (3) What are the stress factors in this workplace setting?

The unit of analysis for the study was the job task. The primary assumption for this study was that the study data would show divergence in necessary computerrelated skills and knowledge between the workplace and those being taught in postsecondary education. Another assumption of the study was that the workplace would influence the job tasks because of the economic purpose, goals for continued economic growth of the company, and cultural patterns that influence performance of the job tasks. The data gathered in this study are descriptive in nature. Written description and quotations were utilized to clarify and present the data.

The rationale for this study arises from an apparent discrepancy between what students are being trained to do and what employees are required to know to promote safe and efficient usage of computers. This lack of information on computer usage in workplace settings and the resulting lack of identified skills and knowledge underlying training in computer usage provided the justification and guiding purpose for this study.

²See Chapter 2, Literature Review, for a discussion of the Job Task Model.

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CHAPTER 2 LITERATURE REVIEW

Introduction

Extensive research exists on the development and design of computer hardware and software components (Carter and Banister 1994; Grandjean 1984; Grandjean, Hunting, and Piderman 1983; Sauter, Chapman, and Knutson 1984; Smith 1996). This review of literature focused on areas of appropriate knowledge and skills related to: (1) the use of computer software and hardware, (2) the standards and guidelines for ergonomic use of computer equipment, and (3) the identification of causes of computerrelated injury.

The sections in this review are (1) computer literacy definitions and related studies, and (2) ergonomic standards, models, and stress factors. Inclusion criteria for articles were date of publication, breadth of topic, and relevance to use of computers. To obtain information for this review, the following word terms were used: (1) computer literacy, (2) postsecondary education, (3) workplace (4) computer usage, (5) ergonomics, (6) injury, (7) stress, (8) human-factors, (9) health-hazards, and (10) training. A manual search of journals and related texts and an electronic search of computerized databases were done to identify reliable sources. Articles were excluded from this review because they were either prior to 1980¹ or were too narrow in focus. However, additional references for related or supportive articles are indicated in this review.

¹The year of 1980 was chosen as a cut-off point for research done on computing systems because of the accelerated rate of change in technologies past that point in time.

Computer Literacy

There is no commonly accepted definition of computer literacy in the postsecondary education system. The following cited theories and studies present suggested definitions and areas of skill and knowledge that have been recommended for effective usage of computers.

Computer Literacy Definitions Based on Conceptual Models

Computer literacy is broadly defined as knowledgeable use of a computer. A category of computer literacy is computer competence, which was defined as observable, objective measures of hardware and software usage by Martinez and Mead (1988). Computer competence is knowledge of hardware and software that allows the student to competently use computing systems. Competence is the foundation of computer usage skills at all levels of education.

Day and Athey (1985) also defined computer literacy as knowledge of programming, software tools, and how computers are used in a cultural, historical, and economic context. Their definition expands the knowledge of technology to include understanding of the role of computers in society, understanding the advantages and disadvantages of computers, and being comfortable with machines. Both Day and Athey (1985) and Martinez and Mead (1988) used definitions that were tied to the usage of hardware and software.

Anderson and Collis (1993) attempted to generate a broad conceptual framework for assessing computer literacy in international educational settings. The population of their survey included principals, computer coordinators, and teachers in elementary and secondary schools in twenty countries. Through gathering of descriptive survey data and use of statistical analysis, Anderson and Collis identified curriculum content areas and created a conceptual model during Phase I of the research. The conceptual framework was evaluated in the context of computer training in eight countries. During Phase II, a curriculum matrix was developed for assessment purposes.

Anderson and Collis (1993) also found that functionality was a component of computer literacy. They stated that functionality for international computer literacy curriculum was "not actually explicitly applied to computer education," but was implied as an underlying skill for computer usage (216). Functionality for computer usage was defined by Anderson and Collis as "the ability to control one's resources to get things done, that is, to function effectively with one's information-related task" (ibid.). Functional abilities included both knowledge and skills.

The ten curriculum content areas identified by Anderson and Collis were

- Computer appreciation for developing a historical or futuristic perspective on the role of computers in society.
- Programming for developing logical discipline through applying problem analysis.
- 3. Human capital for developing vocational applications.
- 4. Educational reform for developing new models of teaching curriculum.
- 5. Constructivism for developing problem-solving abilities among students.
- Functionality for developing knowledge, skills and attitudes related to control of resources with information technology products.
- Empowerment for developing equalized power structures among different social groups.
- 8. Humanism for developing an understanding of humane and social values.
- Economics for developing a conceptual framework of costs and benefits of computer usage.

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 Curricular integration for developing student competencies across subject areas in the general usage of technologies.

It should be noted that some of these content areas were based on philosophies of computer usage rather than on actual usage of computers.

A final working model for functional computer literacy was not established from the Anderson and Collis (ibid.) study because of the changeable nature of technology and differences in how computers were being utilized in educational settings. These researchers concluded that stable curricula for general computer literacy education could not be established due to rapidly changing technology and a lack of consensus on goals of computer education. They also indicated that assessment of students based on functional computer literacy skills proved to be impractical because of disagreement about underlying philosophies related to computer literacy across the diverse educational community.

Computer Literacy Definitions Based on Usage

Taylor (1990) assessed the level of ergonomic awareness within a department of business studies at a British university and found that ergonomic principles were not being effectively taught to the students. Surveys, interviews, and focus groups were used to obtain data from faculty and students. The sample consisted of forty-six students randomly chosen from the total population of 120 students in the program. All twelve faculty members within the department were interviewed. Taylor found that ergonomic problems within the department were more common than expected (80% of students indicated problems arising from the computer work area). Also ergonomic principles were not understood by teachers or students and the subject of ergonomics was seldom properly emphasized in the syllabus for courses although it was considered to be important by the administration (ibid.). Taylor (1990) attempted to link performance of ergonomic practices by students to their knowledge of ergonomics. The weakness of the study was a lack of reported findings on the problems underlying curriculum. Without adequate data on these curricular issues, it was not possible to identify ergonomic principles that were not understood or practiced by teachers and students.

Amini (1993) conducted a study of the degree of self-perceived computer literacy among business students who were not majoring in management information systems. A survey of 123 undergraduate junior and senior students enrolled at a university in Mississippi was used to assess: (1) the characteristics, computer skills, resources, and activities of students; (2) the degree of self-perceived computer literacy; and (3) factors influencing self-perceived computer literacy among students.

Amini's study indicated: (1) a significant increase in skills from class work related to use of spreadsheets, database systems, and statistical or accounting programs; (2) a moderately significant increase in word processing skills, and (3) a small increase in communication software skills (ibid.). Although student knowledge of the common software application programs did increase, their familiarity with more advanced software such as communications, graphics, and programming remained quite low. Amini concluded that this lack of advanced training indicated the academic program followed a traditional microcomputer curriculum found in the United States and Canada.

Seventy-five percent of the students in Amini's study perceived themselves to be computer literate. Analysis of the responses indicated that male students' selfperceived computer literacy arose from prior computer skills, access to a computer at home, and familiarity with a word processing program. The analysis did not identify factors that created self-perceived computer literacy in females. 15

Discussion of Computer Literacy

A definition for functional computer usage skills includes knowledge that allows a person to appropriately use a computer. However, in the Anderson and Collis study (1993), functional computer literacy skills could not be identified because of the diverse missions of the various educational institutions involved in the study. Also, a majority of the content areas proposed for that model were based on intellectual or philosophical goals rather than application goals. Workplace settings are by nature application oriented and are heavily depended on skills-based knowledge and strategies; therefore, computer literacy for the workplace should be based on application not on intellectual or philosophical goals.

Table 2.1 lists the functional skills and knowledge for computer usage found in this review. The general skills areas identified were (1) use of technology (hardware and software), (2) use of programming and logic skills, and (3) use of vocational skills. The general knowledge areas included: (1) understanding computing hardware and software, (2) understanding why and how computers were developed and are being used, (3) understanding computer programming and logic, (4) understanding the implications (disadvantages and advantages) of computer usage, and (5) knowledge of ergonomic principles.

The factors in Table 2.1 indicate a heavy reliance on knowledge about the usage of hardware and software as the basis of computer literacy. This argues an underlying bias toward skill-based computer literacy. Taylor's study (1990) identified a perceived need for students to know and apply ergonomic principles to the usage of computers. However, a knowledge of ergonomics or skills related to applying ergonomics were not found in definitions of the skills and knowledge for computer usage outside of business schools.

Table 2.1 Functional Needs for Computer Usage

Basis of Definition	Skills	Knowledge
Training Amini (1993)	 Greater exposure to computers prior to entry into formal class work Familiarity with a word-processing program 	
Taylor (1990)	(1) Applying ergonomic principles	(1) Understanding and knowing how to apply ergonomics
Academic Literacy Anderson and Collis (1993)	 Ability to program Ability to work in vocational applications Problem-solving abilities Competence in general use of computers 	 Understand a model for curriculum Knowledge of how to control technological resources Knowledge of humane and social values related to computers Understanding of the cost and benefits of computer usage
Day and Athey (1985)	 Using computers as tools designing computer applications through programming 	 Understanding the role of computers Understanding advantages and disadvantages of computer usage Knowing how to program
Computer Competency Martinez and Mead (1988)	(1) The ability to create a software program	(1) Knowledge or understanding of technology and software

Ergonomics

The following studies present a survey of ergonomic research related to causes of injury. Sauter and Swanson (1996) stated that causes of injury are divided into musculoskeletal topics (i.e., ergonomic standards and biomechanical application of the standards) and psychosocial issues (i.e., stress factors). This section of the review is organized on that basis.

In the section on musculoskeletal issues, a job task model is presented and discussed to give a framework for understanding the interaction of job tasks with the computer tools and the work environment. Following the discussion of the job task model is information related to ergonomic standards and workplace applications.

In the section on psychosocial issues, studies related to stress factors in the workplace are presented. A definition of biological, psychological, and environmental stress is also provided. The biological and environmental elements of stress in this review are related to factors found in job tasks and workstations that lead to injurious behavior. The psychological elements of stress in this review are related to the interaction between people and machines, other people, or situations.

Musculoskeletal Issues

The definitions of computer literacy (see above) do not include ergonomic standards or related skills as a part of a standard microcomputer curriculum. Rather, ergonomics has been considered to be a critical part of the training industrial design engineers receive in order to design appropriate furniture and equipment for manufacture. The following job task model is used in workplace settings to design ergonomically appropriate environments.

Job Task Model Theory

A job task model, widely implemented across a variety of jobs within the International Business Corporation (1989), was developed for design of work areas based on job tasks. This model provides a way of perceiving the relationship between the various elements associated with the labor required to produce a product.

The primary factors in the job task model are (1) task, (2) tool, and (3) the workstation and the surrounding environment. The content of work is what is being done and the context of work is how and where it is being done (Baker 1989). The context of work creates variations in types of tasks, tools, environments, and training to meet user needs (see Fig. 2.1).

The guidelines for design of the workstation in this job task model were based on human measurement and efficiency factors in workstation design. The design 18



(2) environment and placement of tools relative to tasks

(3) types of tools for performing tasks

Fig. 2.1. Representation of the Job Task Model

standards for workstations are based on standardized anthropometric data gathered from general adult populations. Modifications to the workstation design are made to meet individual needs or variations in job tasks.

Ergonomic Standards.

A workstation configuration may be based on ergonomic guidelines for the arrangement of furniture and hardware. One such guideline is the voluntary national standard ANSI HFS 100-88 currently being applied to computer work areas (American National Standards Institute 1988).² Work area standards set by the United States military establishment for typists in the 1940s were modified for computer workstations through anthropometric-based research on usage of video display terminals (VDTs, i.e. computer workstations). This created the current ANSI standard for VDT usage (Human Factors and Ergonomics Society 1995). The current ANSI standard includes recommendations for: (1) amount of working space, (2) chair seat height and

²This is a voluntary, not mandatory, nationally recognized standard for design of work areas based on anthropometric data and research. The American National Standards Institute (ANSI) issues these guidelines to encourage design of standardized parts and equipment. This specific standard is applied to computer workstations. However, these guidelines are disputed by some ergonomists as incorrect. There are differences between the ANSI and the international, recommended standard, ISO 9241 (Smith 1996).

adjustability, (3) keyboard height and angle, (4) monitor screen adjustment and distance from the viewer's eyes, (5) reduction of screen glare, (6) lighting, and (7) worker breaks and exercises.

The ANSI VDT standard is a guideline for product design and production standards. It was developed to:

- codify areas of common agreement between scientist and human factors engineers,
- 2. provide guidance on the VDT workplace to designers and users,
- address VDT equipment design and also common features of the VDT workplace and its environment, and
- represent the US. position in international ergonomic standard-setting activities for the next several years. (Smith 1996, 114)

The Occupational Safety and Health Agency (OSHA) (1995) proposed an *Ergonomic Protection Standard*. This standard would provide information for setting up workstations and training employees on prevention of work-related injuries and potential health risks (Radwin 1995). The *Ergonomic Protection Standard* will require all employees be informed about the risks associated with their working environment (health and safety issues).³ However, this standard is not proposed for incorporation into any non-work setting such as computer labs used by students.

Ergonomic standards follow the ANSI-HFS 100 recommendations for workstation design; however, ergonomists raise concerns about the adequacy of the standards (Bergqvist et al. 1995; Christie and Gardiner 1990; Grandjean 1984; Grandjean, Hunting, and Piderman 1983). A review of musculoskeletal problems related to VDT work by Carter and Banister (1994) asserted that the ergonomic design of VDT workstations was not an exact science: "Research on the many involved factors has hardly begun, and both the generalizations and validity of currently available research is less than satisfactory" (1632). Carter and Banister indicated that the most important

³As of July 1997, OSHA has tabled the Ergonomic Protection Standard and has not projected further development. However, the State of California adopted an Ergonomic Protection Standard in 1996 that contains elements of the originally proposed OSHA document.

component of a workstation was the chair and the most studied element of musculoskeletal pain was posture.

There are three different identified postures and corresponding chair types for VDT workstation users: upright, backward leaning, and forward tilted (Scalet 1987, quoted in Carter and Banister 1994). The posture recommended in the above ANSI standard is the upright posture for touch typing at a typewriter or a keyboard. The forward tilting chair posture has been recommended by other sources when the operator reads or writes from paper frequently (Dainoff and Mark 1987; Scalet 1987; both quoted in Carter and Banister 1994). The backward leaning posture chair is recommended for tasks requiring mostly screen work when the viewing distance was less critical and when the chair was highly adjustable to provide optimal posture for the operator during a given task (ibid.).

A comprehensive international standard (ISO 9241) is currently being developed by a consortium of economic interests to cover areas in production of workstation components. It includes requirements from various voluntary national standards, including the ANSI HFS 100-88 standard. The ISO 9241 design standard currently is in varying degrees of completion. ISO 9241 Part 3 lists information related to visual displays and is a required international standard; however, Part 4 requirements for keyboards and Part 5 requirements for workstation and posture are draft standards (Smith 1996). See table 2.2 for a list of the standards.

Other research indicates proper viewing distance may vary from the stated standards. Ankrum (1996) has claimed that the only basis for limiting maximum viewing distance is the ability to resolve the characters on the screen. Visual strain can be expected to occur with sustained viewing when the object of view is closer than one's resting point of vergence (RPV). The RPV is the distance that the eyes naturally converge to when there is no object to converge upon, such as occurs in the dark. The

Table 2.2

Furniture component	Range of recommendation ⁴	Comments
Chair Seat height	14.75" to 22" (13" to 20")	The knee angle should be 90° with thighs horizontal to the floor
Seat pan angle	8° back to 15° forward	Support weight of body at the thighs and buttocks
Seat pan depth	13" to 18" (15" to 17")	Less than the length of the thighs
Seat pan width	17.8" (18" to 20")	Wide enough to support buttocks and allow for position adjustment
Seat cushioning	1.5" to 2" thick	Firm foam or multidensity padding with porous fabric cover
Backrest height	19"	Adjustable and contoured to lumbar region
Lumbar support	4" to 9.5"	Located above seat pan
Backrest contour Backrest width Backrest angle	2" 12" to 18.5" 90° to 120°	Adjustable, vertically convex and horizontally concave
Arm Rest	not stated	Palm rest for non-touch typing tasks. Arm rests should not exceed 10" from back of chair and be from 7" to 9" above seat pan.
Base	5 casters	Stable and swivel
Footrest area/ angle	12" to 15.5" less than 30°	Non-skid surface used when operator cannot put feet firmly on floor
Keyboard Height from floor	23.25" to 33" (27" to 29")	Provide adequate leg clearance and comfortable arm posture
Slope	5° to 30° <i>(-5° to 15°</i>)	Based on operator preference and keyboard height from floor
Thickness	1.25" to 2" (1")	Measured from home row
Workstation		
Surface height	23.25" to 33" (23" to 29")	Provide adequate leg clearance and appropriate keyboard height
Leg room width	31" (18" to 25")	Should be 31" at the level of the feet and 23.25" at
Leg room height	23.25" (16" to 20")	the level of the knees
Display Screen		
Viewing distance	15.75" to 36" (11.5" to	Distance from operator to screen and source
Height	27" to 34.75"	Height measured from floor to center of screen

Range of Recommendations for Setting Up a VDT Workstation

⁴Ranges converted from centimeters to inches and nearest quarter inch. Ranges listed in the proposed ISO 9241 standards are indicated in parenthesis and italics font.
RPV averages 45" when looking straight and 35" when looking at a 30-degree downward gaze angle. Another consideration is the resting point of accommodation (RPA) that is the distance the eyes naturally accommodate without a visual target. It averages 31 inches for younger people and gradually recedes with age. (American National Standards Institute 1988)

Studies by Jaschinski-Kruza (1988) and Owens and Wolf-Kelly (1987) indicate the stress of convergence (distance) contributes more to visual discomfort than the stress of accommodation (focusing). Jaschinski-Kruze (1988) found that an eye-screen distance of 40 inches resulted in less eye strain than a 20° distance for persons with both near (20°) and far (40°) RPAs. Both groups had far RPVs. Owens and Wolf-Kelly (1987) found that after an hour of near work, both the RPA and the RPV shifted inward. Only the shift in RPV was related to eye strain.

Although ergonomic theories and methods have been applied to the design of workstations, increased usage of workstations has resulted in an unprecedented growth in repetitive strain injuries (RSI) and musculoskeletal disorders (MSD) in information technology fields (Kiesler and Finhold 1988). Increased reporting of injuries may be caused by better reporting by employers because of threat of citations and fines for under-reporting of cases (Fletcher 1990).

Among the types of reported musculoskeletal disorder injuries (MSD) associated with computer-related injury were repetitive motion injuries (RMI). Of the types of RMI injuries, carpal tunnel syndrome (CTS) was the injury most commonly associated with usage of computer terminals. In the following section, alternative explanations are given for causes of computer-related injury.

Studies of Injury

Carter and Banister (1994) asserted that musculoskeletal discomfort or injury associated with VDT work was linked to static muscular loading of the human system, biomechanical stress, and repetitive work. They stated that "a major cause of musculoskeletal pain during VDT work (and other office work) was the fact that the worker spends most of the day seated" (1632). Carter and Banister indicated the following items as factors in musculoskeletal pain and injuries:

- 1. Awkward positions of the worker while performing tasks.
- Static or isometric work that causes muscle fatigue in back, shoulder, and arm muscles and tendons.
- 3. Inactivity or a lack of movement that reduces circulation and alertness.
- Overuse injury which causes cumulative trauma disorders or repetitive motion trauma such as carpal tunnel syndrome.
- Stress on bone and connective tissues arising from biomechanical wear on structures in the spinal column and gradual degenerative processes.
- Pressure on blood vessels and nerves arising from impaired circulation in legs that occur because of excessive chair seat pressure and excessive flexion of the knees.
- Mental strain and physical immobilization cause muscular tension that activates the system responses of ischema, edema, and accumulated waste product buildup that in turn causes inflammation and pain (Carter and Banister 1994, 1626-1628).

There is growing evidence that MSD may not be caused by purely biomechanical factors such as seated work, awkward positions, static load, inactivity, overuse injury, stress on bone and connective tissue, or pressure on blood vessels and nerves because of a lack of circulation (Carter and Banister 1994). The National Institute for Occupational Safety and Health (NIOSH) (1993) released a report postulating: (1) psychosocial demands and job stress may produce increased muscle tension and exacerbate task-related biomechanical strain; (2) psychosocial demands may affect awareness and reporting of musculoskeletal symptoms, or affect perceptions of their cause; or (3) the association may be related to a causal or correlational relationship between psychosocial and physical demands.

The term "psychosocial" indicates a type of interaction between people, organizations, or external devices such as computers (Aronsson, Dallner, and Åborg 1994; Bergqvist et al. 1995; Christie and Gardiner 1990; Hales et al. 1994). According to Christie and Gardiner, "Humans and computers do not interact in a vacuum, but in the context of a total situation" (275). As a result, not only objective issues (i.e., hardware placement and usage) but also subjective issues or human-centered issues take on importance in understanding the whole computer environment. One of those human-centered issues is the production of stress.

Stress is a term that has no agreed-upon definition. Cohen, Kessler, and Gordon (1995) suggested a theoretical model for the role of stress in production of disease by identifying three broad categories of research on stress: (1) environmental, (2) psychological, and (3) biological. In their unified model of stress process, Cohen, Kessler, and Gordon suggest the following definition of stress: "All share an interest in a process in which *environmental demands tax or exceed the adaptive capacity of an organism, resulting in psychological and biological changes that may place persons at risk for disease* " (italics added, 3).

As early as 1987, Smith (1987) identified potential areas of injury in a review of mental and physical strain at workstations. The review of RSI injuries in Australia by Kiesler and Finhold (1988), as well as those by Aronsson, Dallner, and Åborg (1994), and Hales et al. (1994), indicates proper application of ergonomic practices alone may

not be sufficient to prevent injury. The research findings recommended further study of the causes of injury through focusing on social factors that produce stress.

Smith (1987) reviewed five areas of health issues related to computer use: (1) reproduction, (2) radiation, (3) vision, (4) musculoskeletal injury, and (5) stress. Smith reported that interest in the influence of stress on worker health was evident in the late 1970s. The symptoms of stress that were reported included anxiety, depression, anger, confusion, and mental fatigue. The type of job most affected by stress was clerical and the least affected by stress was professional. Smith indicates that the most likely contributors to stress were working conditions and job features. Precise indicators of the causes of stress were not identified in the review.

Aronsson, Dallner, and Åborg (1994) in a study of Swedish state-employed VDT users found that there was a relationship between the work organization and a mental/physical stress model relevant to work. Five groups were studied ($\underline{N} = 1738$) over a two-year period: (1) data entry, (2) data acquisition, (3) interactive communications (both data entry and acquisition), (4) word processing, and (5) programming jobs (i.e., programmers, system specialists, and designers). Data were collected through standardized questionnaires that contained previously validated psychosocial factors.

The stress model in this study included general stress arising from work, control issues, influences from social support systems at work, stress reactions related to computer use, and shift length. The underlying premise of the Aronsson, Dallner, and Åborg (1994) model was that workers react to stress as a consequence of an imbalance between job demands, the individual's control of work flow, and the individual's ability to cope with these factors. Aronsson, Dallner, and Åborg surmised that the quantitative and qualitative overload or underload and task pacing were critical to job stress and the function of worker control over these demands was a good

predictor of stress reactions and stress-related disease. The following information summarizes their findings.

Aronsson, Dallner, and Åborg (1994) found that variations in job demands, job control, social support, and health factors did contribute to job-related injuries. The data indicated all job types used computers on a daily basis.

A greater proportion of people with data entry jobs spent more than six hours a day on a computer. A majority of all types of jobs considered the level of difficulty of work (78% to 90%) to be about right. The job groups most vulnerable to computer breakdown were the data entry and data acquisition groups. These groups had no alternative way to complete their jobs when the system was not functioning which caused this group of workers to experience increased levels of stress.

All job types believed that using a computer was a form of assistance rather than a source of job control by management. About 25% of the users believed they did not have sufficient information on the consequences of computerization on their jobs. More data entry and data acquisition workers felt they did not have sufficient training to understand the design and functioning of computer systems

The employees with less specialized jobs (i.e., data entry, data acquisition, and word processing) felt they had greater opportunities to get assistance with their jobs than the employees with more specialized job types (i.e., programmers, system specialists, and designers). This was attributed to the fact that the specialized workers were the only workers who could do their type of job.

Significant differences in health concerns were found between the groups in this study, especially between the data entry/acquisition jobs and the programming jobs. Headaches and general stress were most common to data-entry jobs (36%) and lowest among programmers, system specialists, and designers (18%). Female data entry clerks experienced more headaches than male data entry clerks (29% versus 11%);

however, this may be explained by the fact that more women were employed as dataentry clerks than men (women, $\underline{N} = 291$; men, $\underline{N} = 82$). The incidence of illness or health complaints rose sharply among people working over six hours a day at a VDT (from 22% to 50%) and whose job was data entry.

Programming jobs were the only group that obtained job satisfaction in terms of job demands, job control, and social support. Although this group reported experiencing relatively good health, a question was raised by the researchers about the long-term implications for work because of the dominant "overtime culture" for programming jobs.

There were strong indicators from the Aronsson, Dallner, and Åborg (1994) study that stress factors influenced worker health over a period of time. The strengths of this study were the size and the longitudinal nature of the study. However, there were no controls for possible outside stress factors that may have been influencing the workers during the study (especially family-related factors such as children at home, spouse, finances, etc.).

Hales et al. (1994) found in a study of telecommunication industry workers that a variety of environmental, organizational, and psychosocial factors contributed in the occurrence of upper extremity musculoskeletal disorders. Hales et al. studied job control, work pressure, workload, customer hostility, fear of being replaced by a computer, lack of production standards, high variation in tasks, and little interaction with other workers.

Self-administered questionnaires were used by Hales et al. to identify musculoskeletal disorders that were then verified by medical examination. Also the questionnaires gathered information on the following variables: (1) worker demographics, (2) work organization and practices, (3) psychosocial factors, (4) information about electronic performance monitoring, and (5) keystroke information. Statistical analysis of these variables was used to create a series of predictive logical models. The sample population (N = 518) consisted of telecommunication workers from three different cities. The majority of the sample was white (74%) and female (75%) with a mean of: 37.5 years of age, service of 6.2 years, and 11.5 hours of exercise per week. Factors found to correlate to injuries in various areas are as follows:

- Neck: routine work, bifocals, lack of productivity standards, fear of being replaced by computers, high information processing demands, little variety in tasks, and increasing work procedures.
- Shoulder: fear of being replaced by a computer and number of times arising from the chair.
- Elbow: fear of being replaced by computers, routine work lacking decision making opportunities, surges in workload, and race (non-white).
- Hand-wrist: thyroid condition, high information processing demands, and job title.

Possible explanations for upper extremity disorders in hands and wrists were the number of keystrokes and job monitoring, but these factors did not emerge as risk factors. Job title had the strongest association with hand/wrist disorders. The job title with the highest incidence of hand/wrist disorders was not data input, but rather a job that was the most intellectually demanding (i.e., loop provisioning activities that require high levels of job knowledge and job training in order to solve complex problems).

The Hales et al. study (1994) represented a large random sampling of one type of workplace setting. The findings present generalizable data to other types of work closely related to computer usage in similar environments; however, the findings have not been replicated across other types of workplaces that may be influenced by different task factors. The indicated association between job title and injury may have implications for identifying populations at risk for injury in other professions closely associated with computer usage.

A study of individual, ergonomics, and work organization factors related to musculoskeletal disorders in neck, shoulder, back, and hand problems by Bergqvist et al. (1995) found a variety of factors influenced injury. A population ($\underline{N} = 260$) of visual display workers was studied through observation, questionnaires, and medical examination.

A multivariate analysis of the suspected factors identified the following strong influences in each type of injury:

- Combined neck/shoulder discomfort: limited rest breaks, static work
 posture, too highly placed keyboard, stomach reactions, negative
 affectivity, or age less than forty.
- Intensive neck/shoulder discomfort: stomach reactions, repeated work movements, or a monitor too high for viewing comfort.
- Tension neck syndrome: women without children, women with children at home, limited rest breaks, or a keyboard positioned too high for the worker's arms and hands.
- Cervical diagnoses: age above forty, use of glasses, static work posture, presence of glare, stomach reactions, or tiredness reactions.
- Any shoulder diagnosis: female, limited rest breaks, low task flexibility, or stomach reactions.
- Arm/hand discomforts: extreme peer contacts, extensive overtime, hand in non-neutral position, low keyboard placement, or stomach reactions.
- Any arm/hand diagnosis: age above forty, women with children, smoking, extreme peer contacts, limited rest breaks, non-use of lower arm support, or stomach reactions.

8. Lower back discomforts: stomach reactions, or insufficient leg space.

Berqvist et al. (1995) explained that the individual factor of women with children at home indicates a higher prevalence of musculoskeletal problems because of the double-shift effect (work and then caring for children after work). They also indicate that the stomach reaction factor was predictive of muscle problems when it was correlated with organizational factors or ergonomic factors.

The organizational factor that appeared to most influence injury was the amount of break time. Limited opportunity to take unscheduled breaks was associated with tension neck syndrome, any shoulder discomfort, and arm/hand problems. Limited breaks and static posture also were highly related to neck, shoulder, and cervical disorders. People with stomach disorders who had extensive peer contacts also showed stress reactions; however, the incidence of musculoskeletal discomfort was low. The lack of breaks appears to be a significant contributing environmental factor in the injury process.

The ergonomic factor in the Berqvist et al. study considered to be problematic was keyboard position because of the complex interaction with other factors. The vertical position of the keyboard and neck/shoulder problems showed a positive association; however, the keyboard position and arm/hand problems showed a negative association. They suggested remedial measure to reduce injury should include adjustability of keyboard position and angle according to the needs or preferences of the worker.

The strength of the Berqvist et al. (1995) study was it created a statistical model of the interaction of various factors; however, the complexity of the interactions precluded precise recommendations for reduction of injury. Also the individual factor of stomach reaction appears to be symptomatic rather than an actual cause of injury. Further study and clarification of this interaction model may reveal other associations

Table 2.3

Summary of Factors Influencing Computer-Related Injury

Type of Injury	Job Demands/Control Factors5	Biological or Individual Factors ⁶	Ergonomic Factors ⁶	Social Support Factors ⁶
Neck	Routine work, lack of productivity standards, high information processing demands, little variety in tasks, increasing work procedures, limited breaks, static work posture	Bifocals, stomach reactions, negative affectivity, age below 40, female with/without children at home	Too highly placed keyboard, too highly placed monitor	Fear of being replaced by computers
Cervical Neck/Arm	Static work posture	Age above 40, use of glasses, tiredness reactions	Presence of glare	
Shoulder	Number of times arising from chair, limited rest breaks, low task flexibility	Female, stomach reactions		Fear of being replaced by computers
Elbow	Routine work lacking decision making opportunities, surge in workload	Race		Fear of being replaced by computers
Hand-wrist	High information processing demands, job title, extensive overtime, limited rest breaks	Thyroid condition, stomach reactions, age above 40, female with children, smoking	Hand in nonneutral position, low keyboard placement, non-use of lower arm support	Extreme peer contacts
Lower back		Stomach reactions	Insufficient leg space	
Headaches	Extended data-entry	Female		
General stress	Extended data-entry			
General illness	More than 6 hours per day on computer, job title			

⁵Factors from the Aronsson, Dallner, and Åborg study (1994) ⁶Factors from the Hales et al. (1994) and the Berqvist et al. (1995) studies

with causes and factors. See table 2.3 for a summary of the factors associated with injury from the above studies.

Models of Injury

The reviewed studies identified potential factors that can directly or indirectly cause injury through computer usage. Pheasant (1991) proposed a model of pain and injury derived from the study of musculoskeletal disorders. Pheasant stated that musculoskeletal disorders are the result of a process of static loading of muscles and

repetitive motions that cause muscle fatigue. In turn, inadequate rest and buildup of waste products or intensity of workload may trigger a pain-spasm cycle. Pheasant's view of injury is one of progressive overuse in imperceptible stages starting with mild discomfort. Once established, the pain cycle is easy to reactivate because of neural memory. Stress can also start the cycle because people tend to tense their muscles when they are stressed. Fluid congestion in the muscle can trigger the pain cycle.

Grieco (1986, cited in Carter and Banister 1994) proposed a pain-spasm cycle common to back injury that develops because of feedback to the body from mental strain and immobilization. These two factors cause muscular tension and activate body system responses of ischemia, edema, and accumulated waste products that in turn causes inflammation and intensifies pain and spasm through a feedback loop (see Fig. 2.2).

Discussion of Job Task Model, Ergonomic Standards, and Stress Factors

The above review presents multiple factors related to the design and production of furniture and tools found at a computer workstation as well as variables such as a job task model and causes of injury related to computer usage. The job task model defines a relationship between the type of task, the tools, and the physical environment in which work is performed.



Fig. 2.2. Speculative Model of Work-Related Musculoskeletal Disorders

A discipline that utilizes the job task model to design workstations is ergonomics. The function of ergonomics is to examine the type of job task and determine the appropriate elements of the workstation. An underlying assumption of the job task model is that the workstation is designed by a person knowledgeable in ergonomic practices and standards for the worker who is not necessarily knowledgeable in ergonomic practices and standards. The apparent design assumption is that the worker will not adjust the workstation environment after it has been created. It is assumed that the workstation has been optimized for the individual worker and will require no further adjustment. This may not be the case in a dynamic work environment.

In the workplace, a workstation is set up to accommodate one individual who is performing either one type of task or a range of related tasks. However, a needed skill in a workplace setting might be how to readjust the workstation if the environment is changed because of new tasks or added equipment. Workers need to understand how to apply ergonomic principles to each workstation they use because they may perform job tasks in a variety of places or they may have to modify their work area as task change and no ergonomic specialist is available.

Taylor's (1990) discussion of computer literacy did not indicate why students were not able to successfully apply the principles of ergonomics taught in their curriculum. It is possible that the students were not capable of generalizing ergonomic principles designed to set up a workstation for one person. It is also possible that the ergonomic design standards do not readily express the type of information users need in order to adjust equipment for their use.

The various ergonomic standards (e.g., U.S. MIL STD 1472, ANSI/HFS 100-88, ISO 9241 as stated in Smith 1996) have been developed with two intentions: (1) to provide guidelines for standardized production of equipment and furniture, and (2) to insure the ergonomically designed equipment or hardware is usable by people (Smith 1996). However, the standards may not be easily translated into task information that will help reduce injury by someone using the equipment.

For example, the ISO 9241 international standards for a monitor display specify a viewing distance minimum of 300 mm (11.6") and a maximum 600 mm (23.2") with a minimum viewing angle of 5° below horizontal and a maximum viewing angle of 45° below horizontal (Smith 1996, 211). The distance of the monitor from the viewer determines the following image characteristics that are production standards not usage standards: character height, stroke width, character height to width ratio, fill factors between characters, character format, character size uniformity, between characters spacing, between word spacing, between line spacing, linearity, orthogonality of image edges, luminance, luminance balance, contrast, luminance uniformity, polarity for characters based on task, blinking, flicker, jitter, and color differences. The average user of computer monitors could not adjust these characteristics nor would he or she know when or why these characteristics should be adjusted.

The design standards do not insure reduction of injury; they only insure uniform production standards. The issue remains of determining what people need to know to reduce potential injury based on their personal needs, physical dimensions, and variance in how they perform their job tasks.

The incidence of injury for musculoskeletal disorders has not only risen as computer usage has increased but has also not significantly decreased this decade through application of ergonomic standards (Bergqvist et al. 1995). This may be explained by an interaction of factors other than ergonomic standards. The studies of factors leading to injury (Aronsson, Dallner, and Åborg 1994; Bergqvist et al. 1995; Hales et al. 1994; Smith 1987) indicate that the incidence of injury related to nonergonomic factors was noteworthy and should be further explored. Also the model of

injury proposed by Pheasant (1991) and the review by Carter and Banister (1994) indicate that computer-related injury may arise from the accumulation of micro-injuries over a long period of time. If this is the case, then identifying the underlying causes of injury becomes important for the long-term management of worker health.

Summary of Literature Review

Computer literacy in educational settings includes multiple areas of concern related to cultural values, historical values, economic values, and performance standards. However, computer literacy has not included training related to ergonomic usage of computer equipment nor does it include understanding of stress factors that may lead to injury.

The job task model provides potential areas of research to identify skills and knowledge for computer usage. Within the model, the factors of (1) tool, (2) workstation, (3) environment, and (4) task should be investigated for potential concerns and identification of appropriate skills and knowledge.

The existing voluntary standard ANSI HFS 100-88 and the emerging international standard ISO 9241 are primarily design standards for production of computer components and furniture. Although these standards are essential for uniform production and design of components in a workstation, they were not created specifically as guidelines for usage to reduce injury. The need exists to extract easily understandable information from these standards that promote health and safety and that promote control of the work environment by workers.

Another area for research is stress factors that may contribute to computerrelated injury. The incidence of injury and the link to stress has been identified since the late 1970s (Smith, 1987). The stress factors identified by Aronsson, Dallner, and Åborg (1994) and the links discovered by Hales et al. (1994) and Berqvist et al. (1995) between stress factors and specific types of injuries strongly indicate that the causes of stress and potential injury should also be components of computer literacy.

CHAPTER 3 METHODOLOGY

Introduction

The focus of this study was to identify skills and knowledge for computer usage in a contemporary workplace. A case study methodology was chosen as the qualitative research approach for collection of data. The following sections present the (1) design of the study; (2) design rationale; (3) site and participant selection information; (4) methods and instruments; (5) procedures for data collection, reduction, and coding; (6) a discussion of ethical concerns related to this study; and (7) issues of validity and reliability.

Design of Study

A research site was chosen for the study based on the predetermined criteria of (1) a large number of employees actively engaged in daily use of computers to perform their job tasks, (2) a workplace heavily involved in production of information services or products, and (3) management that was supportive of the study.

A single case design with guiding questions was used to identify functional needs for usage of computers in one workplace setting. The two underlying assumptions in this study were: (1) there would be a difference between the workplace and education settings in the skills and knowledge needs for usage of computers and (2) the workplace would influence how computers were being used.

The unit of analysis for this study was the job task. It was used to guide data gathering in categories related to the job task model: (1) kinds of job tasks, (2) usage of tools to perform job tasks, (3) workstation design to perform job tasks, and (4) stress factors arising from job tasks that may cause computer-related injury. The data were

gathered through analysis of company records, interview and questionnaire responses, and observation notes. Ten participants were chosen through a purposive selection from the available population at the work site based on their job title and their daily use of computers to perform job tasks.

The job task model was used to create guiding questions to aid in collection of data. Those guiding questions were:

- Does the job task model define the areas of computer literacy for individual worker?
- II. Does the type of job task influence the functional needs for computer usage in the areas of training, hardware and software use, individual anthropometric data, and workstation design?
- III. What are the stress factors in this workplace setting?

Appendix A contains the Data Collection Matrix used to coordinate each item found on the research instruments used in this study. An electronic database was populated with the participants' response data and arranged by individual responses to the guiding questions for each instrument or by a listing of all responses to each item found on the various research instruments.¹

Design Rationale

The term *case study* has been linked to that of case history by Hamel, Dufour, and Fortin (1993), who stated that the case study approach grew from qualitative studies in anthropology and sociology. They defined the case study approach as methods for investigation of the object of study within the case.

Case studies have been differentiated from other research designs by the process of interpretation within the context of a situation having specific boundaries for

¹A copy of a completed set of compiled data is available on request from the researcher.

investigation (Cronbach 1975). The characteristics of a case study are that it: (1) focuses on a particular situation, event, program, or phenomenon; (2) uses complete and literal description of the phenomenon to interpret the meaning of the data; (3) illuminates the reader's understanding of the phenomenon through rethinking of the phenomenon being studied; and (4) uses inductive logic to discover new relationships, concepts, and understanding of the unit of study (Merriam 1988).

The strengths of case study research methods are that they provide the means to investigate complex social units consisting of multiple factors that are anchored in real life situations (Merriam 1988). Case studies can generate rich subjective data for use in development of theory and empirically testable hypotheses (Borg and Gall 1989).

The limitations of case study research methods are sample size, extensive amounts of time are needed to properly conduct and analyze the data, the final report is voluminous, and the researcher can oversimplify or exaggerate a situation if proper bias controls are not used (Merriam 1988). Limitations to qualitative studies arise from issues related to reliability, validity, and generalizability.

The issues of reliability and generalizability to case studies arise from quantitative methods used to control the research sample through random selection and sample size. Quantitative methods promoted generalizability of the findings to a general population. However, the population selection in a case study is based on a limited set of highly representative members of the group being studied. The findings from qualitative research are not generalizable beyond the case being studied, but the theories arising from the study may be further tested and applied in other situations (Cronbach 1975; Fetterman 1989; Hamel, Dufour, and Fortin 1993; Merriam 1988; Yin 1989).

The issue of case study validity is judged from the evidence presented and the accuracy of that data (Fetterman 1989; Merriam 1988; Yin 1989). A discussion of validity issues for this study is provided in the following section on linking data to the

research questions and on determining the criteria for interpretation of the findings (see below).

Components of the Study

This study was conducted with the research methods proposed by Yin (1989). Yin defined the primary components of a case study design as: (1) the study questions, (2) the study propositions or assumptions, (3) the unit of analysis, (4) the logic linking the data to the propositions, and (5) the criteria for interpreting the findings (ibid.).

Study Questions

The study questions for this research were derived from a review of literature on the topics of computer literacy and ergonomics. Within the review of literature, a job task model was identified as a representative model for designing or identifying the various components of labor (job tasks, tools for performance of the task, and the workstation configuration for efficient performance of the job task). Also within the review of literature related to ergonomics, a strong link was identified between stress factors and injury related to computer usage. It was therefore determined that the job task model would serve as a basis to direct areas of inquiry in this study and that the additional area of stress factors would also be investigated because of the possible link to computer-related injury.

Study Assumptions

Yin (1989) suggested that the scope of a case study is further focused by propositions or assumptions about the area of inquiry. There were two underlying assumptions in this study. First, it was assumed that the study data would indicate a difference between the workplace and education settings in the skills and knowledge needs for usage of computers; and second, the workplace would influence how computers were being used.

Unit of Analysis

The unit of analysis in a case study directs the focus of research for the case under investigation (Merriam 1988; Yin 1989). In this research, the unit of analysis was the job task, which is the basis of the job task model. This unit of analysis was deemed to be more appropriate to guide this study than analysis of the organization or analysis of the individual because the job task was central to the issue of underlying skills and knowledge necessary to efficiently use a computer. The job task provides a closer match to the activities underlying computer literacy and the types and frequencies of injury related to computer usage.

This unit of analysis was utilized to identify the kinds of job activities in the workplace, the hardware and software tools begin used to perform tasks, the design and usage of workstation areas in performance of job tasks, and stress factors arising from performance of job tasks.

Linking Data to the Research Questions

The data from the recorded interviews and field notes were entered into an electronic relational database for retrieval and analysis (refer to a description of the relational database in the section on data reduction found later in this chapter). The database was organized by individual answers to specific interview questions or questionnaire items. The database could be viewed as a layout showing all of the answers to one question or item, or as all of the answers given by one participant within that research instrument. Written description of events and participant quotations were also used to clarify and present the findings to the research questions.

Criteria for Interpreting the Findings

One method for interpretation of the data in this study was to compare the data with the reviewed literature. Another method used to interpret the data was the use of triangulation of the data through multiple sources or events. For example, data related to ergonomic standards and the job task model were analyzed in three ways: (1) analysis of the job tasks of the workers to determined if the job task model adequately represented the flow of work (see Fig. 2.1, p. 19); (2) comparison of the participants' workstations to the suggested ergonomic adjustments in table 2.2 (p. 22 of this document); and (3) fit of the tools to the task as determined by the responses to the questionnaires, interviews, and observations. Data related to stress factors were compared to table 2.3 (p. 32) for factors influencing injury and were also analyzed against multiple responses given by the study participants.

Delimitations of the Study

This study focused specifically on understanding the interaction of the various components of the job task model and stress factors within one workplace. This boundary to the study delimits the study to identifying the underlying skills and knowledge within the workplace that may be used at a later time to validate curriculum in postsecondary education. It was not the purpose of this study to investigate postsecondary curriculum during this phase of research but rather to understand the foundation of skills and knowledge arising from the workplace. The findings of this study form the basis for a future study of curriculum in postsecondary education that is specific to the content of training for academic disciplines.

Limitations of the Study

The case study methodology utilizes intrusive observation of a small sample within a specified population that is determined to be highly representative of the case

being studied. The intrusive observation methodology is used to gain an understanding of the focus of research but does not provide statistically generalizable data because of the small sample size (Borg and Gall 1989; Hamel, Dufour, and Fortin 1993; Merriam 1988; Yin 1989).

In order to increase the range of possible application of the findings in this study to other populations, the researcher controlled the sampled population through the type of job task performed. The participants in this study were those people who were suggested by the supervisors in the company and who agreed to work with the researcher. During the course of the study through observation and interviews, the researcher determined there was no inappropriate bias introduced into the study by the company through their selection of participants.

Site and Participant Selection

An engineering company that designs software and electronic chips for graphical display of image databases was chosen as the research site. The company had heavy involvement in the usage of computers, had a sizable population of employees working at a professional job level with computer technology, and was willing to allow the study. The company was incorporated as a research organization in 1968 in order to produce computers with computational capabilities not available in the existing hardware market at that time. The company currently has an active role in world markets for its products.

The company was initially approached through a letter requesting access to its personnel and facilities in order to conduct the study. Through a series of telephone contacts and e-mail messages, the study was tentatively approved pending a meeting to clarify research matters for the company. The meeting to state the intent of the research

and clarify related issues was attended by the researcher, her committee chairman, and five members of the safety committee at the company.

The meeting resulted in approval for the study and support from members of the safety committee for arranging contacts within the company. The safety committee was interested in supporting research that would investigate computer usage to determine potential safety problems as well as provide information that could be used for future training of employees.

The initial design of the research stipulated ten participants for the case study. However, during the clarification meeting, the chairman of the safety committee expressed a desire for the researcher to look at all types of work areas within the company (i.e., government simulations, entertainment/education simulations, commercial simulations, database engineering, graphics systems, application and program engineering, product development, shared technology, product support and design, mechanical technology, manufacturing and associated functions, accounting/finance, and human resources). It was agreed after discussion in the meeting that the researcher would look at all types of work areas for safety issues and report them to the safety committee but would not include non-computer using areas within the actual case study data.

However, after the meeting was reported to the director of human resources, the director determined that only ten people would be allowed to participate in the study due to the economic impact of an estimated five hours of time per person as well as the impact on the work load of the employees. Therefore, ten people working at a professional level of employment and heavily involved in computer usage were selected to be in the study.

As part of the agreement to allow research within the company, the researcher agreed that a statement emphasizing the study was being done to provide information

for academic training would be made to each participant in the study. This was important to the members of the safety committee because they did not want participants to think employees were going to get new furniture because of the study. The purchase of new computer furniture would only be considered by the company after review of reported injury cases of employees who had been diagnosed with a computer-related injury.

Participants

The company had 717 employees as of June 19, 1996, and at the time of the study was hiring for a variety of positions. Of the 717 employees, 44 were minorities and 168 were females. Of the 293 technical professionals, 16 were minorities and 34 were female.

At the onset of the case study, the researcher reviewed the various types of jobs within the company to determine which areas would best represent a purposive sample of the professional population. The review of literature indicated a possible link between job title and musculoskeletal disorder (MSD) injuries. To establish this link to MSD injury, a review of the OSHA 100 Log² of injuries for the years of 1994 and 1995 was conducted. The review indicated a high frequency of computer-related injury in the job categories of software engineers and database engineers. The types of injuries considered by the researcher to be computer-related were determined to be a type of MSD injury (e.g., carpal tunnel syndrome or repetitive motion injury) or an injury that indicated pain or strain to a part of the upper torso (i.e., neck, back, arms, wrists, or hands). Strain was considered to be a type of computer-related injury because it could arise from improper posture or weakened muscles (see fig. 2.2). Contusions,

²The OSHA 100 Log is the document for logging and summary of injuries for the Bureau of Labor Statistics. The document indicates date of injury, person being injured, occupation, department, description of injury, and extent of and outcome of the injury. The log must be kept for five years.

punctures, crushing injuries, fractures, fainting, and abrasion were not considered as a type of computer-related injury because the cause appeared to be from accidental processes rather than long-term processes usually associated with computer-related injury (refer to the models of injury presented in the literature review).

The incidence of injury could be explained by the number of employees in those job titles as well as the possibility that those job titles had factors that caused increased incidence of injury. Table 3.1. below, includes data from 1991, 1992, 1994, 1995, and six months of 1996. The data from 1993 was not provided because it was either misplaced or not collected that year.

After the review of the OSHA 100 Log, a purposive selection of job title areas was done to locate employees working in a job title identified for inclusion into the study because of the incidence of injury. Those job titles included software engineering, database engineering, network or system operators, and network engineering. These job titles were targeted as possible areas to draw participants from because (1) there was evidence from the OSHA 100 Log of past injury related to these types of job tasks, (2) the jobs required heavy usage of computers on a daily basis as the primary tool for production of work, and (3) the employees in these jobs were considered to be at a professional level of job tasks rather than a clerical level of employment. Clerical level positions were excluded because those positions may be filled without postsecondary education training.

A member of the safety committee who worked in human resources agreed to call supervisors in the suggested areas. This is the written explanation of the human resource specialist of what she told the supervisors:

The safety committee had been working with someone from Utah State regarding ergonomics training and issues and that the company had agreed to have [her] interview ten of our [professional technical] folk and observe them working in order to complete a study that [she is] doing to determine what ergonomics training was needed for [professional technical people] as

Table 3.1

Summary of Job Titles and Associated Injuries Reported in OSHA 100 Log³

Job Title	Injury	Year
Computer Operator	lower back strain	91
Computer Operator	hand puncture wound	92
Contract Administrator	laceration to head	94
Contract Coordinator	mild thoracic outlet irritation	92
Customer Engineer	puncture wound to hand	92
Customer Service	repetitive motion injury/shoulder	92
Data Analyst-Database	contusion to right hand	94
Database Administrator	pain and numbness in both hands, arm, back	94
Database Coordinator	lumbar strain	92
Database Engineer	cervical strain	91
Database Engineer	paper cut on eye	91
Database Engineer	acute cervical strain	92
Database Engineer	repetitive motion injury to both wrist	92
Database Engineer	fainted	94
Database Engineer	crushed middle finger, left hand	94
Database Engineer	carpal tunnel	96
Designer	thoracic muscle strain	92
Engineer Manager	pain in both wrists, hand, arm, numbness	95
Engineer (Sr.) Hardware	pain in both hands, wrists, forearm	95
Geometry Modeling	carpal tunnel, right hand	94
Technical Illustrator	neck and shoulder strain	92
Graphic Engineer	right hand, arm pain	94
Information Analyst	knee and forehead abrasion	92
Marketing Supervisor	injury to left little finger	94
Mechanical Engineer	fractured tailbone	94
Mechanical Engineer	eye injury	95
Net Specialist	hematoma to big toe	92
Office System Analyst	strain in groin	91
Printed Circuit Design	eyebrow laceration	92
Project Coordinator	sprain to knee	91
Software Distributor	acute lumbar strain	92
Software Engineer	ankle sprain	92
Software Engineer	thoracic strain	92
Software Engineer	repetitive motion injury to right wrist	92
Software Engineer	tendonitis both wrists	92
Software Engineer	cumulative trauma syndrome both wrists	92
Software Engineer	back pain while working/sitting	94
Software Engineer	contusion to left elbow, tailbone, back	94
Software Engineer	soreness pain in right hand and arm	95
Software Engineer	pain in both hands (carpel tunnel)	95
Software Engineer	pain in elbow, arm, shoulder, neck	95
Software Engineer	carpal tunnel syndrome	96
Sr. Computer Operator	contusion above eve	94
System Analyst	repetitive motion injury to both wrist	92
System Analyst Programmer	pop in neck (torrecollis)	94
System Operator	hand and wrist sprain	92

³Those injuries that were considered to be possible MSD injuries by the researcher are underlined in this table.

they went through school. Also that it might require up to 5 hours of a person's time spread over a month, but that some of this time would be just observation and perhaps videotaping.

The actual time frame for the researcher to contact supervisors and potential

study participants continued over approximately six weeks. The reasons for the

length of time to make these contacts were availability or responsiveness of the

supervisors or the availability of employees to talk to the researcher.

Each supervisor was telephoned or e-mailed by the researcher. The following

description of the study was given to each supervisor to distribute to potential

volunteers within his or her department:

I am conducting a study of computer usage based on curriculum from postsecondary education. Your company is allowing me to work with you to obtain information. The kinds of things I will be looking at are how you learned to use a computer, what kinds of hardware and software you know how to use, how you set up your work area, and stress factors related to work. This information will be used to train students at a university level.

I am looking for college graduates to participate in this study. I am interested in what graduates need to know based on actual workplace needs.

The study consists of a set of questionnaires (related to hardware, software, job tasks, and workstation design) and follow-up interviews. I will also observe how you do things related to your job tasks (for example: how you keyboard, how you arrange your work area, etc.) And you will get to give me opinions on workstation design, functional needs in hardware, software, and how to reduce stress related to work.

The actual time for participants I estimate to be 5 hours which can be spread out over several weeks (no more than one month). There are 2 or 3 interviews that will be arranged so they will not conflict with your job demands.

All responses from participants are confidential and voluntary.

If you are interest in participating in this study, please send me (Vicki Napper) an e-mail response. My e-mail address is: student@cc.usu.edu.

After waiting for three or four days after the initial contact with the supervisor,

the researcher again attempted to contact each supervisor to determine if there had been

a response to the request for study volunteers. Most supervisors were called or e-

mailed multiple times before names of employees for the study were obtained. Over the

course of six weeks, the names of thirteen employees were provided to the researcher.

Those people were approached by the researcher with her request for their participation

in the study. The final selection included five participants working in hardware production jobs and five participants working in software production jobs. Of the ten participants, seven participants were male and three were female. Three people were excluded from the selection because of issues related to their availability or cooperation.

Each potential participant was interviewed and advised of the content of the study. Each person was asked if he or she was agreeable to being in the study. Of the final total of ten participants, the researcher determined that only one person had volunteered; the rest of the employees were requested to participate in the study by their supervisors. Seven of the employees were aware of the description of the study given to their supervisors, but three employees were not aware of the purpose of the study and were participating solely because of a request from their supervisor.

Inclusion Information

The information collected from each participant included: (1) age; (2) sex; (3) highest educational level, institution of degree program, and program of study; (4) date of graduation; and (5) date of employment in the general field of information systems. The final criteria for inclusion in the study were:

- Employment in a profession related to computer usage for a minimum of three years.
- (2) Daily use of a computer system.
- (3) Strong familiarity with at least one kind of computing platform (PC, UNIX, Sun workstation, VAX, etc.).

In the initial research proposal, inclusion requirements for selection also included a degree in a field related to information systems. However, the academic degrees of the participants were across a variety of disciplines not necessarily related to information systems. Therefore, it was determined by the researcher that the job

placement and resultant computer-dominated job tasks were more important to the purposive selection for inclusion in the study than emphasis on the type of achieved degree.

The final purposive selection of participants included employees heavily involved in daily computer usage across a variety of tasks within the engineering departments (refer to table 4.1, page 78 for demographic data on participants). It is important to note that the researcher had no initial choice of participants in those job titles other than by the type of job task they were performing and for female participants after seven male participants had been suggested.

The researcher verified that supervisors assigned personnel who were available and willing to participate in the study (responses to *Third Interview*, Question 9). Although the supervisors chose participants for the study, it is unlikely that the choice of participants by the supervisors was directed by anything other than availability of participants at the time the request was made for participation in the study. Seven participants indicated their supervisors did request volunteers before they assigned someone to the study.

The reasons for supervisors allowing participation were not explored fully. One supervisor did express interest in the study because of the effects of carpal tunnel syndrome on a member of his family. Participants were asked why they believed they had been assigned to the study and they had no explanation other than they were available or that they knew the researcher had requested to work with a woman (responses reported from *Third Interview*, Question 9).

The human resource contact within the company for the researcher stated that the choice of cooperating supervisors was based on who the contact personnel perceived would be likely to allow employees to participate in the study. Several suggested supervisors did not respond to messages from the researcher and one

supervisor stated only volunteers from his department would be allowed to participate—there were no volunteers from his department.

Methods and Instruments

During the course of negotiation for access to company personnel, the amount of time required to conduct the study became important because of restrictions placed on the researcher by the company. In the initial research proposal, case study data were to be collected through extensive usage of unstructured interviews and unscheduled observations. However, the researcher was restricted to five hours of total time with each participant in the actual study.

In order to effectively use the amount of participant time available to gather data, the data collection methods were modified to include a series of open-ended response items on questionnaires as well as a set of open-ended interview questions that were presented to each participant. Observation of the participants was restrained to one hour of time per participant.

Research Methods Used During the Study

The following methods were used to collect data. These methods are consistent with qualitative research methods for case studies suggested by Yin (1989).

Interviews

There were three interviews: (1) an interview to clarify answers to the first two questionnaires (e.g., history of computer usage--hardware and software--and computer literacy) and obtain data about the achieved level of computer literacy; (2) an interview to assess workstation usage, job tasks, and perform observation; and (3) an interview to identify stress factors related to the job tasks and the workplace. The interviews

were conducted in this sequence in order to move from less sensitive information about the history of the participant to what the researcher believed would be more sensitive information about the current work environment. The interview on stress was done last because the researcher determined the content of the responses to those questions would be more personal and, therefore, more threatening to the participants. In order to obtain meaningful responses from participants, the establishment of trust is a recommended research procedure (Fetterman 1989; Guba and Lincoln 1981; LeCompte and Preissle 1993). A greater degree of trust may be established between the researcher and the study participants based on successive conversations and positive interaction between the researcher and participant.

Procedures for collection of data through interviews were based on an underlying assumption of qualitative research that participants are capable of reporting their own reality (Eisner 1991; Fetterman 1989; Goetz and LeCompte 1984; Hamel, Dufour, and Fortin 1993; LeCompte and Preissle 1993; Merriam 1988; Yin 1989). Triangulation of data was used to identify potential areas of conflicting responses within self-reported data. Items on the various instruments were analyses for patterns of responses among the participants. A pattern of response could include such things as the same stated procedures for getting a task done by many individuals or identification of the same source of a problem for multiple individuals.

One area of concern in qualitative studies is that of researcher bias. The researcher was aware of her bias in the area of reported injury; therefore, extra caution was used in allowing participants to report their own experiences and understanding of workplace injury. The researcher utilized techniques suggested by Krueger (1988) that are associated with focus group methodology and assist in reduction of researcher influence on the data (i.e., listening, unobtrusive control, lack of response to statements).

Scheduling and conducting interviews. Interview times were arranged with the participants and available conference rooms were scheduled for that time slot to provide privacy during the interview. When the researcher arrived on site, the participant would be called to escort the researcher into the secure building and to the scheduled conference room. The researcher was not allowed to roam freely in the building without an escort.

At all interviews, an audio tape recorder was placed on the desk and a microphone was placed on the table in front of the participant. Each session was recorded for later transcription. On a few occasions, the participants gave additional information after the tape recorder was turned off. When appropriate to the purpose of the case study, the information was recorded in the field notes.

Each succeeding interview was scheduled after completion of the previous interview and was based on time availability of the participant. Scheduling of time with each participant depended on his or her work deadlines, trips off-site, or scheduled vacations. All interviews were conducted during regularly scheduled work hours (8:00 a.m. to 5:00 p.m.). The total time to complete the study for each individual was consistently four hours or less; however, the span of time from the beginning of data collection to the end of data collection varied greatly (two weeks to three months) because of job demands or crisis situations that arose which caused participants to cancel and reschedule interviews.

First interview (history and use of computer hardware and software, and computer literacy). The History Of Computer Usage Questionnaire and the Hardware/Software Usage Questionnaire were discussed and clarified during the first interview. The questionnaires had been electronically sent to the participants after the initial meeting to allow them time to compose responses and then electronically return data to the researcher previous to the scheduled interview.

An interview form was also used to guide data collection related to the accumulated computer skills and knowledge. The data are reported in the findings section related to tasks and tools.

Second interview (job tasks, workstation arrangement, and observations). The purpose of this interview was to obtain data about job tasks and workstation configuration. The interview was conducted in the participant's workstation. This interview also included a questionnaire on frequency and location of job tasks, an Ergonomics Concern Quiz, a VDT Workstation Assessment, and a videotaped observation. These data are reported in the findings on workstation usage.

Third interview (stress factors). The final interview was conducted in a scheduled conference room with the use of a series of open-ended questions to elicit information on stress factors in the workplace. This interview was used to identify how job tasks and deadlines were assigned, who assigned these activities, and how the participants felt about deadlines, and to probe for other factors that caused stress at work. This interview also identified what the participants did to reduce stress, how they perceived injury, and how they would handle an injury if it occurred. The responses to this interview are reported in the findings on stress.

Instruments

There were five instruments used in this study: (1) History of Computer Usage Questionnaire; (2) Hardware and Software Usage Questionnaire; (3) Job Responsibilities and Task Locations Questionnaire; (4) OSHA Draft Document, VDT Workstation Assessment (Occupational Safety and Health Agency 1995); and (5) an Ergonomic Concerns Quiz (see Appendix D for copies of the associated forms). The questionnaires were not part of the original research plan, but they were developed in order to control the amount of time and consistency of the data across the research categories. The items in the questionnaires were based on the guiding questions proposed for the study.

Some degree of content validation occurred after the questionnaires were given to the first three participants. It was found the items "self-taught" and "use of books, manuals, on-line documentation" on question 2 on the History of Computer Usage Questionnaire was considered to be redundant. This was collapsed into one item for analysis. Question 6 of the Hardware and Software Usage Questionnaire was found to duplicate information requested in question 5 of the same form (i.e., Question 5: What kinds and brands of hardware do you generally use to do your job tasks? Question 6: What are the various components on your computer system?). The respondents provided the necessary information for both questions in question 5.

History of Computer Usage Questionnaire. The purpose of this form was to determine types of training necessary in academic settings prior to employment in a technology intensive profession. This questionnaire also established what sources of information each participant felt were important (rank ordered) for learning to use computers. The findings are reported in the section on tasks.

Hardware and Software Usage Questionnaire. This questionnaire was used to establish the kinds of hardware and software with which the participants were familiar from training in postsecondary education and from use of their current workstation equipment. The results are reported in the findings on tools.

Job Responsibilities and Task Locations Questionnaire. The review of literature indicated that computer-related injury rates were associated with frequency of computer usage and stress factors. Therefore, the purpose of this form was to provide additional data about how computers were being used and to identify any potential risk areas for computer-related injury.

The frequency of the job tasks was assessed to determine how often the participant performed a task. The choices were daily, weekly, every two weeks, monthly, quarterly, or yearly.

The location of the task was used to establish if a participant was utilizing a computer in performance of the task. The two areas where computer usage was thought to occur were in the participants' assigned workstations and in the shared workstation areas. The other choices for task performance included a work area without a computer, a conference room, an area away from the company location, and an area out of town. Those tasks that were performed daily at a computer terminal were considered to be the most likely to be associated with computer-related injury because of frequency and type of physical activity. The results are reported in the findings on job tasks.

The data obtained from the rating of importance of tasks were not used in the study findings. This rating was not analyzed because it was determined there were a variety of factors that could influence the participants' perception of the importance of the job tasks.

VDT Workstation Assessment. The purpose of this form was to gather data about the type of ergonomically appropriate equipment available in the work areas. The VDT Assessment Form was taken from the Draft Document Ergonomic Protection Standard (1995, Appendix B: Addendum B-1, Video Display Unit and Keyboard Issues Checklist) for the sole purpose of assessing areas not meeting ergonomic standards for the workplace being studied.

The researcher filled out the form after measuring the workstation furniture (chair height, table height, monitor viewing distance and viewing height, keyboard height). Question 3 of the form (knowledge of chair features available from the manufacturer) was eliminated as inappropriate to workstation assessment. Verbal responses to Question 25 were gathered from the participants.⁴ The results are reported in the workstation findings.

Ergonomic Concerns Quiz. The purpose of this document was to provide data relevant to training people how to set up and to use equipment in a workstation. The Ergonomic Concerns Quiz form was adapted from a picture of a workstation found in the Draft Document Ergonomic Protection Standard (1995, Appendix B: Addendum B-4, Figure B4-3). The adapted version indicated five additional areas of concern for injury that were identified from the literature review (i.e., viewing distance, shoulder posture, foot position, angle of forearm at elbow, and work surface area). The assessment items were marked with numbers and named (e.g., back support, line of sight, etc.) to facilitate uniform responses to the instrument.

The quiz was handed to the participant at the end of the second interview and the participant was asked to verbally respond to each item by telling the researcher what was important to know about the item. Their responses were recorded. The purpose of the quiz was to triangulate the accuracy of the self-reported data of the participants' understanding of ergonomics. The results are reported in the workstation findings.

Observation

Two types of observation occurred during the study. One observation was of the assigned cubicle with the participant actively using the workstation and the other observation was of the shared work areas where the participant performed job tasks away from his or her assigned cubicle. Assigned workstation observations consisted

⁴ Question 3 required information on availability of different types of seat pans from the manufacturer. Question 25 required information about previous training on posture, work methods, how to adjust workstations, awareness of risk factors, and how to seek assistance for concerns.
of (1) watching the types of motions and tasks of the participant and (2) documenting the configuration of the workstation environment.

The observations were done on the day of the second interview. However, on two occasions participants were observed in his or her shared work area prior to the observation of his or her assigned workstation. The reason for these early observations was that the opportunity arose to observe the participants engaged in tasks related to a deadline crisis or problem-solving activities.

A hand-held carncorder carnera was used to videotape the participants performing daily job tasks as well as the positioning of the items in the workstations. The primary purpose of the videotape was to provide placement information about equipment, arrangement of images on monitor screen, and the overall feeling of the participants' work areas. Videotaping provided a visual record of the type of actions the participants performed rather than the duration of the tasks due to a lack of time. The frequency of the task was provided through the Job Responsibilities and Task Locations Questionnaire.

One area of concern during the videotaping was the presence of proprietary items in the workstation areas. The researcher had to obtain a camera permit from company security to allow a videotape camera or 35-mm camera to be used in the secure buildings. The camera permit specified the type of equipment, purpose of the equipment, and a duration of time (one month) that the camera equipment would be allowed into the buildings. Employees at the company were aware that they should question the presence of any recording devices about which they are unsure and request to view a camera permit before allowing anyone to videotape their work area. Several participants did request to see the camera permit before allowing the researcher to videotape their area. Also before the researcher videotaped any area or participant, a release form was given to the participant to read and sign. All participants signed the form that stated that the videotaped footage was to be used for research purposes related to the study. The researcher asked each participant before videotaping if there was anything present in the work area that should not be videotaped. There were no such items indicated.

Data Collection, Reduction, Coding, and Reports

A typical order of data collection for the study was pursued during the study. Each interview session was recorded on audio tape cassettes and the workstation observations were recorded on videotape. The information recorded on the audio tapes was transcribed into word processing computerized files that were saved and the data was then transferred into an electronic database (*FileMaker Pro*). The word processing data files were coded according to the interview, the instrument within the interview, and the item number on the instrument. Two verbal reports were delivered to the company within the initial two months following data collection and a copy of the final dissertation document at the end of the defense process. With the permission of the chairman of the safety committee, a copy of the fifth chapter was also given to the participants in the study. The following sections provide an in-depth explanation for these procedures.

Data Collection

The average duration for collection of data per individual in the study was four hours. The following is a synopsis of the order of the events in the study (see Appendix C for a full description of events):

1. Prospective participants were contacted by e-mail to obtain personal data.

- An initial meeting was arranged with the prospective participant to inform him or her of the proposed study intent and content.
- Copies of the History Of Computer Usage Questionnaire and the Hardware and Software Usage Questionnaire were given to participants.
- The researcher created a quick pencil sketch of the general layout for each participants work area.
- 5. The first interview (history and usage of computer hardware and software, and computer literacy) was completed with each participant to clarify points on the questionnaires and to gather information on computer literacy for the specific participant's job.
- 6. The second interview (job tasks, workstation arrangement, and observation) was conducted to investigate job tasks, obtain measurement of the workstation, verify the layout drawing of the area, complete the VDT Workstation Assessment form, administer the Ergonomic Concerns Quiz, and observe the participant performing routine job tasks.
- 7. The third interview (stress factors) was completed.
- The audio tape data were transcribed and mailed to each participant for clarification and correction if needed.

Data Reduction

All data were entered into an electronic relational database (*FileMaker Pro*). Files were created that contained the data from each participant. The data could be viewed in two formats: (1) the entire text of transcribed responses for each participant or (2) the accumulated answers from all participants to each interview question or questionnaire item (see Appendix D for the complete set of forms). These layout formats of the database allowed the researcher to review the data by entirety of one participant's responses or by the accumulated responses to one question by all participants. This method for organizing the data proved valuable in identifying both the patterns and unique responses reported in the findings.

The findings were reported through both summaries of data and quotations of participant responses to each question. It was found that because the researcher was not attempting to control the flow of the participant responses, the responses often contained information that varied from the original question that was asked. As a result, wherever quoted responses contained information not related to the unit of analysis (job tasks), the responses were edited to report only data on the topic being presented. Care was taken to indicate edit points through the usage of ellipses in the responses. The full text (approximately four hundred pages from thirty hours of audio tape recordings) of the transcribed data is available on request from the researcher.

Coding

In order to provide anonymity to the participants in this study, each participant was assigned an alias name and code number. The participants whose jobs related to hardware production (hardware engineers and mechanical engineers) were number coded between 11-15 and were given alias names beginning with the letters "a" through "e." The participants whose jobs related to software production (software engineers and database engineers) were number coded between 21-25 and were given alias names beginning with the letters "f" through "j." Participant codes do not reflect any specific order or purpose other than for reporting the data by job type (refer to Appendix B for the specific interview/instrument coding and alias names used in reporting the participant responses).

Reports of Findings to the Company

Two verbal reports were given to the safety committee prior to completion of the final dissertation document. The initial verbal report delineated the workstation findings against the proposed assessment documents obtained from the Draft Document Ergonomic Protection Standard (Occupational Safety and Health Agency 1995). Also during that meeting, a copy of the spreadsheet of all OSHA 100 Log injuries for 1991, 1992, 1994, 1995, and the first six months of 1996 was given to the members of the safety committee who were present at the meeting. The spreadsheet showed the types of injuries within the company according to the types of typical injuries occurring in each type of job. A shorter version of the spreadsheet showing only the injuries reported from among professional job categories (i.e., engineers of all types and managers) was also given to the members present at the meeting.

A second verbal report presented the initial findings that related to injury and safety within the company. This report presented information about types of stress factors found in the review of literature (a copy of table 2.3 was provided), types of stress factors present in the company, and identified areas of potential concern for stress-related injury within the company.

A copy of the study was given to the chairman of the safety committee at the end of the defense process. With permission from the chairman of the safety committee, a copy of Chapter 5 was also given to the study participants.

Ethical Concerns

The proposal for this study was submitted for review of ethical concerns related to human subjects and was accepted by the oversight committee for research at Utah State University. No significant ethical concerns were identified. The human concerns in this research were (1) that the participants be aware of why they were participating in the study, (2) that participants were aware of their rights during the course of the study, (3) that participants were aware of how information from the responses given to the researcher would be reported, and (4) that participants were aware how the videotaped information would be used.

To insure the participants were aware of the purpose of the study and willing to cooperate with the researcher, the potential participants were interviewed one-on-one before there were allowed to participate in the study. At that time, they were told what the study was about, given an estimate of how much time would be required to participate in the study, given an overview of the type of information the researcher would require of them (questionnaires, interviews, observation), and told that the information would be recorded as anonymous responses to the guiding questions in the final report. A statement of items perceived by the researcher as important for completion of the study was given to each participant during the pre-study interview so that he or she would understand what was expected during the study well as the rights he or she had during the study. The participant was asked to read the paper before being asked to participate in the study. This is a copy of the information given to the participants:

I am conducting a study of computer usage based on curriculum from postsecondary education. Your company is allowing me to work with you to obtain information. The kinds of things I will be looking at are how you learned to use a computer, what kinds of hardware and software you know how to use, how you set up your work area, and stress factors related to work. This information will be used to train students at a university level.

- As a participant in this study you have rights. Those rights include:
- (1) The right to schedule meetings with me that do not interfere with your job deadlines. However, it is very important that you make an effort to work with me to complete this study as soon as possible.
- (2) The right to review all information you give me and correct it for content and meaning.
- (3) The right to clarify any questions I may ask you which you don't understand or are concerned about.
- (4) Confidentiality in the final report.

Please contact me at any time at the above e-mail address or phone number. (I have an answering machine and will return calls as soon as possible.) It is very important that you make an effort to work with me to complete this study as soon as possible.

At completion of the study but before analysis of the data, all of the interview tapes and observation notes related to the participants were transcribed. A copy of the compiled data for each participant was mailed to that participant for review. No participant received copies of data other than his or her own data.

The participants were told they were expected to contact the researcher within a month with any content that was either incorrect or misleading. The researcher then contacted each participant after the elapsed month for corrections or concerns before the findings were written. No changes were requested.

Role of the Safety Committee

The safety committee at the company is composed of employees from a variety of departments within the company and who had a job that required them to be involved in safety issues. The initial contact with the company to request permission to conduct this study was through the director of the human resources who passed the request to the chairman of the safety committee. After internal debate on the merits of the study and its value to the company, the safety committee chairman requested authorization from upper management to sponsor this study. After authorization was given to proceed on the study by upper management, the members of the safety committee provided assistance in locating information within the company and assistance in contacting supervisors to obtain participants for the research.

In return for supporting the study, the safety committee requested (1) that the researcher make certain the participants understood the purpose of the study was to gather information for training postsecondary students and (2) that they a final report of the findings. Also, any problems that might have required intervention from someone

within the company were to be handled through a member of the safety committee (e.g., conflicts arising around participation in the study, scheduling problems because of work load, etc.).

Role of the Supervisor

The supervisors were selected by a member of the safety committee who worked in human resources. The supervisors were chosen by type of job they supervised and by perceived willingness to cooperate with the study. The researcher had minimal contact with the supervisors other than to identify potential participants for the study.

The potential exists that the supervisors may have manipulated the selection of the people for the study. An incident reported by a participant tends to negate that concern. The incident occurred at the end of the three study interviews with that participant. The participant reported that his second-level supervisor—not immediate supervisor—told him not to participate in the study after the first interview because it was taking too much time. The participant told me he had decided not to claim any hours on his time sheet for participation in the study, and he had only used his personal time while assisting in the study. This participant had been recommended for the study and had not volunteered. No other participants reported any problems arising from participation in the study or indicated any reason they would be selected other than being available at the time of request.

Role of the Researcher

The researcher was presented to the participants in the study through referral by their supervisors. At all times, the researcher stated she was a graduate student doing research on how computers were being used in the workplace and the information was being used for a final research project. There was no attempt by the researcher to assume any position in the study other than as someone seeking information about predetermined areas of inquiry.

Issues of Validity and Reliability

There are four tests for judging the quality of a research design. Those four tests are (1) content validity, (2) internal validity, (3) external validity, and (4) reliability (Borg and Gall 1989; Merriam 1988; Yin 1989). These tests for validity can be assessed through use of appropriate tactics during the process of completing of the case study (see table 3.2 for a summary of tests and case study tactics used in this research design).

Content Validity

Content validity is represented by the degree of investigation of content items represented in the study (Borg and Gall 1989). The recommended tactics to establish content validity are through (1) the use of multiple sources of evidence, (2) establishment of a chain of evidence, and (3) participant review of draft reports. Multiple sources of evidence were collected through interviews, questionnaires, observations, videotaping, and field notes based on a match between the Data Collection Matrix and guiding questions in the study. These sources of data were tied together as chains of evidence through the usage of the Data Collection Matrix and the relational database. Data were assembled in the relational database by the question being answered to form collective responses to each question.

The draft document of the findings was not reviewed by participants because the company stipulated that no participant was to be allowed additional time beyond the initial requested time for the study. Due to this limitation, the researcher opted to use participant review of his or her own data to validate content. Table 3.2

Summary of Tests and Tactics for Establishing Validity

Test	Case Study Tactic	Phase of Research
Content validity	Use multiple sources of evidence	Data collection
	Establish chain of evidence	Data collection
	Have participants review draft report	Composition
Internal validity	Use pattern matching	Data analysis
	Use triangulation	Data analysis
	Use member checks	Data analysis
	Actively involve participants	Data collection
	Repeat observation	Data collection
	Use peer examination	Data collection and analysis
	State assumptions and bias	Pre-Data collection
External validity	Establish similarities between the case and a broader category of the population	Research design
Reliability	Use case study protocol	Data collection
	Develop case study data base	Data collection

Internal Validity

Internal validity is the process of establishing causal relationships and making inferences (Yin 1989). Merriam (1988) has suggested that internal validity of a case study is established when the investigator establishes a credible reconstruction of the multiple realities of the participants. The tactics recommended by Yin (1989) and Merriam (1988) to establish internal validity are through (1) pattern matching, (2) triangulation of data, (3) member checks, (4) active involvement of participants, (5)

repeated observation, (6) peer examination of findings, and (7) a statement of assumptions and bias prior to research.

A pattern in the data is considered to be a similarity of circumstance or action. Pattern matching assisted in finding common areas of knowledge and skills or associated factors across the various categories being studied (i.e., job tasks and associated tools, ergonomic standards, and stress factors). Pattern matching also helped to identify common factors across the different types of jobs (programming, database engineering, electrical engineering, and mechanical engineering). This process of inferring patterns was assisted by comparing the identified factors or data gathered with the information found in the review of literature (tables 2.1, 2.2, and 2.3).

Triangulation of data was accomplished through use of multiple methods of data collection (open-ended interviews, questionnaires, assessment instruments, and observation). Also, triangulation was provided through use of guiding questions to allow uniform investigation of the research categories during review of the data in the relational database.

Member checks were accomplished by giving each participant a copy of the transcribed text of his or her interviews and questionnaire responses for comment and correction. The participants did not have access to any data except the data from their interviews. Active involvement of the participants occurred at the onset of the study when they were informed about the reason for the research. Also the participants were asked to comment on various emerging issues as they became apparent within the study.

Observations of all participants were performed while the participants were in their workstations. Although each participant was not observed on multiple occasions

because of time constraints placed on their time in the study, the object of observation (job tasks) was observed multiple times in multiple areas.

Peer examination was performed by soliciting responses on the emerging issues from working ergonomists as well as other authorities in the area of computer usage. Validation of findings from peer sources also occurred through comparison of the findings to the studies cited in the reviewed literature.

The assumptions about the study were stated prior to the onset of the study in the research proposal. Concerns for researcher bias were reduced through utilization of techniques associated with focus group methodology (Krueger 1988). These techniques (e.g., lack of response to statements, listening, unobtrusive control) have been validated as effective methods to reduce researcher influence on the participant responses.

External Validity

External validity is the process of establishing generalizability beyond the immediate case study (Yin 1989). Although qualitative research is not considered to be statistically generalizable, it can establish general principles that apply in one specific condition or circumstance in time that may also apply to a similar condition or circumstance in time (Merriam 1988). In this study, the sources of data came from participants working in different categories of jobs and in different departments within the company. However, the findings indicated there were general patterns of activity or similarities of problems that spanned job categories and departments within the company. This generalization within the company may indicate that the findings could also apply to similar companies with the same types of job categories.

Also, a detailed description of the structure and purpose of the company was provided to allow establishment of the similarity between this company and other

companies providing the same types of services in the area of technology development. Although the job tasks existed within one company, the types of jobs (programming, database engineering, electrical engineering, and mechanical engineering) are common throughout the technology development industry. This similarity of job type provides a link to a larger population than the immediate case study.

Reliability

Reliability is proven through demonstration of repeatability of the case study to obtain the same results (Yin 1989). The operation of this study has been documented through all stages to allow replication of the study in a different location (e.g., contact and setting up the study, selection of participants, stages of gathering data, and methods for organizing the data). The research methods for obtaining data have been explained and copies of all interviews, questionnaires, and assessment instruments are documented in Appendix D. An additional source of reliability in this study is availability of the audio tapes and the database containing the responses of participants and the observation notes of the researcher as a reference for assessing the reliability of the findings in this study.

Summary

This was a study of a workplace specifically for identifying skills and knowledge related to the usage of computers. A case study design was used and it was delimited to the study of a workplace for analysis of the components in the job task model and stress factors that may cause computer-related injury. The restrictions of the study were related to time and access to the sampled population that were imposed on the researcher by the company where the study was conducted. The study was done at a company heavily involved in development of technology products. A purposive selection of ten participants provided the source of data gathered through questionnaires, interviews, and videotaped observations. The interviews were recorded on audio tape and in handwritten notes. The audio tapes were transcribed into text files and placed into a relational database for analysis. Observations were recorded on videotape and in written field notes.

A relational database was created to organize the categories of data by items in interviews or in the research instruments used in the study. The findings are presented in the major categories of inquiry (e.g., tasks, tools, workstations, and stress factors).

The content validity of this study was established by gathering data from multiple sources, creating a chain of evidence, tying the findings back to the guiding questions of the study, and having participants review their data for accuracy. To establish internal validity, pattern matching, triangulation, active involvement of participants during data collection and analysis, repeated observations of similar environments, and peer examination of data analysis was performed. Also the researcher stated underlying assumptions and biases in the design of the study prior to collection of data. External validity was established through use of study participants who worked in commonly found professions of a type of business currently flourishing in the world economy. The reliability of the study was established through use of appropriate case study protocols and development of a relational database for storing the study data and analyzing the data to answer the research questions.

CHAPTER 4 FINDINGS

Introduction

This study explored the relationship between the job task model and computer literacy within a workplace setting through analysis of the daily job tasks of work. The following findings of the study are divided into three primary areas: (1) tasks and tools, (2) workstations, and (3) stress factors in the workplace that may contribute toward injury. Also a section has been provided to give background information on participants and the company where the study was conducted. This context information is provided to create a meaningful backdrop for analysis of the data as well as for future historical reference.

The tasks, tools, and workstation findings are elements within the job task model. The findings on tasks and tools are presented together because they are dependent on each other for meaning. A task requires tools just as tools are used to perform a task.

The findings about the workstations include information on the physical features of the work areas and an assessment of the work area furniture based on ergonomic standards. It also includes an assessment of the participants' understanding of ergonomics, and information on the participants' understanding of illness and injury related to computer usage.

The final section of the findings is about stress factors in the workplace. The findings on stress present the participants' definitions of stress, what was causing stress in their daily workplace environment, and how stress was being handled or eliminated.

Summary information and supporting quotes from the participants are used to present and illuminate the findings. Although extensive interview data were collected during the course of the actual study, only those data that were directly relevant to the research categories and judged to best answer the research questions were selected to report in these findings.

In order to provide a more personalized account of findings while maintaining confidentiality, fictitious names are used for the participants and the company. The pseudonym used in this study for the company site was Innova. Pseudonyms for the participants were chosen solely on the basis of alphabetical order (i.e., Adam, Brent, Charles, Daryl, Earl, Freddie, Glen, Heide, Irene, and Jeff). At the end of each quoted piece, the participant's pseudonym was used with coding to indicate the source of the data by interview and question response (see Appendix B, Coding for Participants and Forms).

Historical Context of Study

The historical context for the findings of the study are based on two sources of influence: (1) the recent history of working conditions at the company and (2) a general description of professional skills and tasks of the participants. This information was drawn from: (1) researcher notes, observations, and discussions with people associated with the company; (2) questionnaire responses from the participants in the study; and (3) a variety of documents provided by the company.

Company Growth and Working Conditions

This study was conducted at a business in the western United States. The company, Innova, specialized in research and development of computer technology systems and support software to control those systems. Innova was formed in the late

1960s when two researchers split from a university research group and began financing development of their product through use of their own financial resources and outside funding from research foundations. By the 1980s, Innova had grown into a primary source of technology and software for military, government, and commercial markets.

In 1990, the net revenue (\$157,551,000) and number of employees (1,415) reached a peak; however, in 1993, due to cutbacks in government and military spending, Innova began an economic decline. Earnings in 1993 showed a gain of \$1,826,000 and a loss in 1994 of \$5,559,000 (information taken from the 1995 annual report to stockholders). In an attempt to reduce the loss margin, a reduction in personnel began in 1994 with a layoff of approximately twenty percent of the employees. Innova stock reached a record low in that year. In 1994, the board of directors brought in a new president to institute renewal of Innova through changes in the work culture and organizational structure.

Restructuring of Innova began with elimination of the division structure and associated layers of management. The number of employees dropped from 1,283 in 1993 to 717 by June of 1996. Reduction in force was accomplished through a specified percentage across the board in all work areas. Subsequent retirement and resignation of personnel also augmented the reduction of the total work force. By the second quarter of 1996, Innova again registered a net gain in earnings for the first time in several quarters and authorization was given to hire additional personnel in selected growth areas of the company.

In 1996, Innova was composed of business groups (profit and loss centers) headed by general managers who reported directly to the president of Innova. The business groups were focused on specific types of markets (i.e., government, military, and commercial). Within the business groups, layers of management had been eliminated and reduced to a minimal number of managers. Work groups under the

managers had been consolidated to absorb the job tasks from employees laid off or resigning from Innova.

The result of consolidation of job tasks within work groups was that a greater number of employees were being supervised by one manager and fewer employees were working to complete the existing workload. Although the number of employees had decreased, the amount of work required to maintain contractual commitments remained constant. This resulted in all employees working longer hours to complete the same pre-layoff workload. As one employees commented, "A lot has changed in the last three years in that way. There are fewer and fewer people to do the same amount of work. It hasn't gotten any easier" (Jeff 03:1).

A change in the work culture also occurred during the 1993 through 1996 time frame. Innova went from a company with employees comfortable in their market niche and job tasks to one of transformation that was characterized by "energy and enthusiasm" accompanied by a "business attitude with an emphasis on profitable growth, while still preserving the zeal for technology" (quoted from a letter to the shareholders in Innova stock). Employees said Innova used to be a "family" that worked together and shared success with each other, but the family had now become a "business" driven by production goals and profit statements. A study participant describes the change:

When I was hired in, it was a family and people worked for their family. Now it is a business and in order to keep my job, I need to do it very well and I need to be willing. The company is not here for me, I am here for the company. ...But I don't want to go anywhere else. I want to do well here. I want to gain people's respect. I want to be part of the team. It is just part of getting the job done and being willing and happy to do it. (Heide 03:2)

The most pressing economic challenge Innova faced was an ongoing transition of technology from a market based on mainframe technologies to a market based on personal computers (PCs) with the Windows NT operating system. As a result, the product line now included both hardware components and support software to support existing "bread and butter" mainframe markets as well as hardware and software products for the emerging PC market.

Participants and Computer Usage

The employees were also affected by this transition from one type of technology base to another type. They needed to maintain old skills as well as learn new skills. The pressure to compete in a highly changeable technology-based marketplace was an underlying fact of life for the employees. A reply to the question about where technology was going exemplified the certainty of constant change in this workplace:

I don't even know if the decision to go to the NT [Windows NT operating system personal computer system] is the right decision. Most people have told me, yes, that is where industry is going. These Sun Workstations, any workstation, are too expensive and that PCs are getting almost as powerful as these workstations and they are cheaper. They have their limitations, but that is where [Innova] feels the industry is going.

But Microsoft is currently at the top so everyone is going with Windows 95 or Windows NT—it is so dynamic. But ten years ago WordPerfect was at the top as far as word processors go, and look where they are now. They are just barely surviving. A stupid business decision on the part of Microsoft could cause NT not to be the top product anymore, not the way to go. All of a sudden we will be found with all of these powerful PCs with NT on it that nobody uses anymore. How do you predict the future? Right now Microsoft has made the right decisions and that is what has kept them on top for the last few years, but who knows? It might not even be a decision they make. A new product might come out that they aren't involved with, and they are left behind. (Jeff 03:1)

To help their company survive this technological transition, the participants

performed a variety of creative, problem-solving activities both independently and in

conjunction with teams of other employees as well as general, daily tasks (refer to

Appendix E for a list of reported job tasks).

The general tasks included such things as using a word processor, accessing a

database or spreadsheet, and accessing the network for sending and receiving message.

The professional tasks were those tasks that were specialized in nature and were

obtained through training at a postsecondary level. Additional findings will be provided on various aspects of the job tasks in the following sections.

The participants' professional background for performance of tasks came from a wide variety of academic areas (electrical engineering, industrial engineering, electronics, business management, computer sciences, mathematics, and design engineering). The two primary job categories of the ten participants in this study were either hardware-related engineering or software-related engineering. There were five participants from each engineering type.

The participants graduated from their academic disciplines during the time period ranging from 1960 to 1994. Two participants were recent graduates (1994). Six participants graduated in the 1980s and two participants graduated prior to the 1980s (see table 4.1). The participants learned to use computers while attending universities, vocational colleges, or K-12 public education; or at home (also refer to findings about learning to use computers, p. 79).

The above context information about the company and participants is provided as a background for this study. The findings of the factors in the job task model—task, tools, workstations, and stress—present the daily reality in the workplace for employees at Innova.

				Entered	Began Work at	
Participant	Sex	Graduated	Degree	Field of Work	Company	
11	М	1989	MS	1984	1989	
12	Μ	1984	BS	1984	1984	
13	Μ	1989	BS	1983	1983	
14	Μ	1960	AS	1965	1987	
15	Μ	1977	BS	1978	1981	
21	F	1994	BS	1985	1995	
22	Μ	1985	BS	1986	1992	
23	F	1985	BS	1987	1987	
24	F	1988	BS	1988	1988	
25	М	1983	BS	1984	1993	

Table 4.1 Demographic Data on Participants

Tasks and Tools

Computer use at Innova involved not only knowing skills specifically related to hardware and software, but also involved upgrading job skills for use of new products. Computer literacy has been defined in academic settings as "functionality" in use of computers and "the ability to control one's resources to get things done, that is, to function effectively with one's information related-task" (Anderson and Collis 1993, 216).

Functionality in this workplace is defined through the skills required for daily tasks and as skills for the usage of computer tools to perform job tasks. Task and tool skills are further divided into the following sections: (1) learning to use computers, (2) daily job tasks and associated skills, (3) skills needed to use software tools (4) skills needed to use hardware tools, and (5) training others to use software and hardware tools.

Learning to Use Computers

Eight of the participants were initially introduced to computers while in an educational setting. Two participants picked up basic computer skills beginning with home experimentation (see table 4.2).

During the first interviews, the participants were asked to remember and describe the kinds of experiences they had in learning to use computers. Their memories indicated frustration arising from a lack of formal training in academic settings.

My first introduction to a mainframe was "you have an account" and I had no idea what that meant other than I could sit at certain terminals in a building and type my name and a password. I could write files or edit things. It takes awhile to get on top of using a computer. You learn you have storage and that there are programs that are being run and you can invoke them, stop them and store things and print things out to printers. [How did you learn these things?] By trial and error. There was no course or training Table 4.2

Age, Location, and Condition for Learning to Use Computers¹

Hardware Jobs	Age	Location	Condition
Adam	21	home	My father purchased a mail order TI computer. This computer actually had less capacity than the hand- held calculator which I owned at the time, but did have a keyboard and monitor. It allowed for cartridges (of which we had none) and accepted BASIC programming commands. I was not impressed.
Brent	22	university	Programming with APL for physics class.
Charles	15	home	My brother had purchased an early Apple computer.
Daryl	23	vocational school	I was taking training in electronic technology.
Earl	over 21	university	My first year in college, fall of 1966. The department was trying to get some classes into the first years of college in the hopes of attracting more students. This was an introduction to computer math using FORTRAN as the language. Punched card input. We did the punching. Jobs were run in a batch with the next day printed results. This was a large, for its time, mainframe.
Software Jobs	Age	Location	Condition
Freddie	17	high school	The computer sat in the back of the math class, and nobody really knew anything about it. We were told it would eventually be brought into the curriculum.
Glen	13	junior high school	As a reward for receiving the only A on a specific test in my math class, I got to spend a week playing with a desktop calculator while the other kids redid the chapter. The computer had no graphics capability and stored data on punch cards. Most importantly it was programmable. I had fun that week.
Heide	33	university	Business computer class.
Irene	23	university	Used Macintosh computer MacWrite word processor to write a paper for a liberal education class.
Jeff	22	university	In a FORTRAN class.

¹Responses taken from the History of Computer Usage Questionnaire.

associated with that. They figured it was pretty basic and it was. It isn't like I spend hours and days agonizing over it. It is pretty obvious what you need to do at that level.

The way it was back then, they would have various rooms that would have five or ten terminals. I never knew which terminals were connected to which computers. Eventually I got the hang of it because I would log on to one, clearly that wasn't one of them. That was all throughout the building. And you would go and find one that appeared to be on the right computers. [Which computer?] HP 9000. Typically you had to write a program and you had to find the right computer with the correct compiler. (Adam 01: 2; graduated 1989)

There was a mainframe computer at the university. Everyone had to have an account in order to use the system. You had an instructor who gave you a little slip of paper with an account number and your name on it and told you to show up at the computer lab to do the assignment.

So you get up there in this room without enough terminals and some students who really know what they are doing and they are really busy and some students that are just completely lost and they are going around asking everybody questions. How do I enter this coding so I can get my output so I can take it to class without any understanding of what this stuff is doing. It is just we know if we put this magic number into this box we will get a print out that we will get an "A" for.

The biggest frustration was getting the silly computer to work. Half the time it was down or you missed a period or a comma or had a syntax error of some sort that you couldn't find or couldn't debug² so you spent hours trying to get your IF-THEN logic loops to work correctly. It just became a nightmare to complete an assignment if you could get your user account to work to begin with. Once you got through that hurdle and got all of your passwords straightened out on the thing and you got into the computer and maybe you could get your assignment in and oh, but you had to be sure you could get the right hours to get time on one of these machines because you knew it was going to take you three or four hours. I have fond memories of being up there in the middle of the night and you go down to the parking lot and no cars are there and everyone else is trying to get their assignment in the next day too. (Charles 01:2; graduated 1989)

I used a mainframe at the university. My experience was normal for working with computers. One was [that] it was a large faceless machine that had very specific rules on what you had to do to make it work. If you violated that, it belched out huge reams of paper, and the computer operator got mad at you. The system administrators seem to be about the same. They find belligerent folks for that job all of the time, or maybe it makes them like that. We haven't been able to determine it. Then, software is in a constant state of change. Things that worked last week won't work this week because somebody

² The term "debug" is used to indicate the process of locating problems in computer code. A debugger is part of the computer software (e.g., C++) that allows a programmer to find errors in how the code is written.

changed something that was promised not to affect you. (Earl 01:2; graduated 1977)

They would have old systems that were very slow. That is why I chose to do my work at home. Just with a normal home PC, it was a lot easier and more convenient for me to do it at home. One of the compilers for the ADA³ class— they only had an ADA compiler for the VAX⁴ system, so you had to use an editor like a line editor. It was grunt work to put your code in. Whereas, at home I had an ADA compiler for the PC that had pull down menu options you could use with the mouse. You would just tell it you wanted an IF-THEN statement and it would build it in the right syntax and you could just fill stuff in. Also I could sit there and relax, and I had my home surroundings. I could be more comfortable, and I had my own printer there so I could print things when I wanted to. Sometimes they only had one person who could be there [at the university] to help, a lab aid or whatever, but they couldn't necessarily help with your code or your program. They could tell you the reason you can't see anything on the screen is because the monitor is off. (Freddie 01:2; graduated 1994)

My first actual use of a computer was a word processing kind of a thing I pretty much had a friend show me how to get started. So I got on there and started typing. As you play around with it a little bit more, you pull down the menus and see what is there and try a few things and that sort of thing. For anything more than that, it was when I started getting into my computer classes after deciding to apply to the Computer Science Department. I had one class that dealt with computers. That was my introduction to programming class with FORTRAN. That was basically a similar situation as far as the teachers aids who give you instructions about how to get logged into the mainframe environment and give you your assignment and helped get things set up then kind of let you have at it. (Irene 01:2; graduated 1988)

Learning in academic settings was a singular and mostly frustrating experience.

Participants, who were then students, relied on trial and error or the help of friends in learning to use a computer. Upon reviewing the graduation dates of these participants, it was noted that the lack of guided learning experiences persisted in postsecondary computer labs across the 1970s, 1980s, and the 1990s. One participant reported that her home computer setup was more sophisticated than the one provided for students at her university (Freddie 01:2).

³ ADA is a type of computer language.

⁴ A VAX system is a type of mainframe computer.

The participants indicated self-taught as a way of learning to use computers. Five of the ten participants chose "self-taught" as the primary way they learned to use computers. The other five participants indicated they primarily learned from books or from asking people how to perform a specific task (see table 4.3 for a summary of ratings). In essence, all of the participants learned to use computers by themselves. Also, the participants indicated the primary way they currently learned to use new technology and software products was through self-instruction.

Participants also acquired new computer skills while on the job because it was necessary to increase or maintain their job skills to remain employed. The modes of learning on the job included self-taught, classes at work, and emulation of correct code (responses from First Interview).

In summary, the participants tended to learn to use computers through selfinstruction and while on the job. The participants reported learning about computers through the exploration (self-taught), usage of books or manuals, or usage of on-line documents. They also asked other people for assistance or emulated correct code.

Job Tasks

In both hardware- and software-related engineering, daily activities heavily

Participant	Self	Friend	Family	Grade School	High School	College	Voc-Tec Class	Book	Other
Adam	2		-	-		1	-	3	
Brent	2	1	-	-	-	4	-	3	
Charles	1	2	1	-	-	3	-	-	
Daryl	1		2	-	-	4	3		
Earl	1		-	-	-	2	3	-	
Freddie	1	3	-	-	-	2	2	-	
Glen	1	2	-	-	-	3	-	-	
Heide	2	-	-	-	-	-	-	2	1
Irene	3	-	-	-	-	2	-	-	1
Jeff	1	-	-	-	-	2	-	-	

Table 4.3						
Participant	Rankings	of Lear	ning to	Use	Computers ⁴	5

⁵Rankings range from 1 (most important) to 5 (least important). A dash indicates no ranking given. Not all participants used all five possible rankings.

depended on usage of Innova's Local Area Network (LAN) as well as interaction with people. The network provided status reports on a variety of projects, a means to propose solutions to problems, software applications for designing products, a way to document designs, and a general method for communicating with people at all levels of the company (data taken from Second Interview, Question 4).

Types of Job Tasks

The job tasks were identified as primary tasks performed by each participant. The job task descriptions reported by each participant, the frequency of each job task, and the contact with computer equipment are reported in Appendix F. See Appendix G for a complete listing of job tasks sorted by frequency, location, and importance of tasks.

The types of tasks completed at a computer varied from job to job. However, the general categories of computer-related tasks were management of data (i.e., data retrieval and data entry), generation of ideas (i.e., programming, creating schematics, report writing, creation of presentations), and testing of products (debugging software or digital analysis of hardware components).

The participants were asked to identify where they performed each job task in order to establish if the participant had contact with computer equipment. Participants were also asked to indicate how frequently they performed the task. The data, reported below, indicate the frequency of contact while performing a job task as daily, weekly, or less than weekly. The job location ratings have been transformed from locations ratings to dichotomous ratings of "yes" or "no" ("yes" indicates the task was performed at a computer workstation; "no" indicates the job task was not performed at a computer workstation).

Of the seventy-one reported hardware-related job tasks, thirty-five were performed at a computer (nine daily; three weekly; and twenty-three less than weekly). The other thirty-six job tasks were not performed at a computer (two daily, eight weekly, and twenty-six less than weekly).

Of the forty-nine reported software-related job tasks, forty-three were performed at a computer (eleven daily, seven weekly, and twenty-five less than weekly). The other six tasks were not performed at a computer (one weekly and five less than weekly). Eighty-seven percent of the total software-related job task were performed at a computer (43 of 49 total) whereas 49% of the total hardware-related job task were performed at a computer (35 of 71 total) (see table 4.4).

The types of task varied because of the differences in the products produced by the engineers. Understandably, the percentage of job tasks requiring computer contact was higher for software-related jobs because software exists only in computer memory, whereas hardware components exist outside of computer memory. Hardware-related job tasks required other types of non-computer-related tasks (e.g., visual inspection for flaws, physically moving the product to another location for testing, or testing with a digital logic analyzer to verify the physical location of a problem on a logic board). This difference in the physical handling of the products was a fundamental difference between these two general job types.

The Flow of Work

The flow of daily job tasks for hardware engineers generally began by checking the network postings for status of jobs, assignments, availability of parts, and corrections or changes to existing products. This is a description of one participant's morning routine:

Table 4.4

Type of Job Task	Daily	Weekly	Less Than Weekly
Software job task with computer contact	11	7	25
Software job task without computer contact		1	5
Hardware job task with computer contact	9	3	23
Hardware job task without computer contact	2	8	26

Reported Frequency of Job Tasks and Contact with Computers

I come in every morning and check Issues⁶ to find out what items are waiting for my approval. . . . Typically you have SCRs [System Change Requests] assigned to you and it is your job to sort through them and figure out what is wrong and solve them and track that information. . . . At which time you do a ECO [Engineering Change Order] that may involve calling up a schematic to make a change on it. . . . You can actually pull up a schematic at your workstation. You are using the same tools you are using to do the actual work downstairs so people can check it out and get you a new board. You invoke the view-draw package and bring up a window to see the schematic. You can design chips or you can design whole boards or whole back planes for whole systems. Same tool does all of that. The simulation tools are right here. You have some synthesis tools. This is an all purpose workstation. (Adam 02b:4)

Software production also had phases of design and production. However,

because software existed only inside of the computing systems and depended on the

capabilities of the computer, the approach to design and production was different.

In [our area], all we know is that a certain machine has new capabilities. We sit down with our supervisor and look at what we can do to exploit the new capabilities of the system and figure out what we can do using our existing tools and whatever I can hack together. We get in our minds the visualization of the end product with the following functionality based on the capabilities of the systems. Then we build the database design documents to explain what is there and how it behaves. What can and cannot be done. (Glen 02b:4)

⁶ Issues was a system designed by Innova to track and manage ECOs (Engineering Change Orders), CARs (Corrective Action Requests), SCRs (System Change Requests), documentation, and other "issues."

For a typical bug fix or enhancement whether I discover them or someone came to me and said I need the software to do this, I would probably have to define and detail what that includes. Get it down to real specifics. . . . When someone comes to me with a problem with the software, I have to get a lot of detail from them. I ask, "How were you running it?" "What were you doing?" "What was your exact command line?" "What were your exact circumstances?" I get all of that information from someone, then I come and sit down at my workstation. If it is a bug fix, then I sit at my workstation and try to recreate what they were doing and see if I can recreate the same bug that they got and then from there, try to solve it. If it is an enhancement I spend a lot of time looking at the current software and writing some notes as far as what do I need to change to make this enhancement work, that sort of thing, details about the software. I tend to like to write a lot of little notes like this when I'm trying to figure out what the software is doing in order to understand how to enhance it. So, I'll write little notes and write down files I'm looking at or a line number from the source file or a procedure name or something like that and keep notes to myself about what parts of the software will have to change and what the changes need to be. Sometimes I even write code fragments in my note book to see if I can think through it in that way. When I feel pretty good about what I've come up with then I'll start typing and changing the software itself on my workstation. (Irene 02b:4)

Software code or database products were intangible products often remaining in one computing system or area from the design stage until delivery whereas hardware components were physically passed from one area to another. The software assembly process involved creation of new code, modification of existing code, or creation of textures that would be integrated into a database to create a visual image. The hardware assembly process involved inserting parts into boards and hooking electronic equipment to the board to test it. Hardware engineers had job tasks related to production of tangible products whereas software engineers had job tasks related to production of intangible products.

Miniaturization of Production

Innova produced extremely small, complex hardware components that were used to enhance visual images in conjunction with computer boards. For example, one of the chips produced at Innova had 550,000 transistors located on a chip less than .47" square with the minimum feature of the chip being 0.8 microns. This type of engineering is called "very large system integration" (VLSI) because of the number of transistors that may be placed in a small area. This was an environment that required work methods for designing a type of technology that was so extremely small it could not be seen with the human eye. The engineers in chip design used software to help determine the position of the individual transistors in relation to other transistors and in relation to the overall design of the boards. The computations for design of each chip would take the Sun Workstations overnight to complete. Also the only way to determine if a chip would perform as designed before it was produced was through use of simulation software (Earl 02:7).

A participant and a worker not in the study told the researcher about the problems they were encountering with things "getting too small." The following datum is from a field note taken that day:

The first mention of miniaturization was when the participant said that finding trouble in the boards was going to be harder because the boards were now being made with such small parts that test equipment couldn't be physically placed on the trouble areas without destroying the components. The new trouble shooting method was a process that was going to rely entirely on software to locate the problem.

The second occurrence came during a visit of the participant with a coworker of the participant. The topic of conversation was about getting a simpler job because their jobs were getting too complex due of miniaturization of the parts. The co-worker called attention to a bar-coded part or serial number on a sticker on the board. He stated that he couldn't read it and had to get his magnifiers out to see it. At that point, he pulled out a magnifier that looked like clip-on sunglasses but was smaller and much thicker. He said the magnification was 5x. His glasses were already very thick. He also said he saw a serial number on the edge of a board and it was just too small to read. The logic board was very thin, perhaps one-tenth of an inch or less. (Field notes 7/2/96).

Miniaturization of equipment was changing the way the hardware engineers

worked. Hardware engineering was moving away from a hands-on approach to one of

a software interface for design as well as testing. This was already the process in

software engineering. One implication of the miniaturization process may be in how

future engineers are taught to create, modify, manage, and solve problems related to

products that they must mentally visualize because they can no longer physically see them.

Problem-Solving Skills for Daily Tasks

Daily job tasks were a combination of problem-solving actions that included usage of a computer, interaction with people, and interpretation of information. The participants frequently engaged in problem solving with a variety of other personnel: production workers, co-workers, project engineers, and customers. Participants expressed ideas in multiple ways to solve problems.

Oral and written interactions between employees for solving problems included e-mail messages to get suggestions or comments on designs or design changes, face-toface contact through formal meetings with supervisors or product managers, informal meetings at employees' workstations, telephone conversations, and phone or personal contact with non-Innova employees. Of these types of interaction, face-to-face contact was the most common. These are the responses of participants when asked "Do you interact with people while performing your job tasks?"

Yes. I'm almost always working with people. I'm going to sit down and write this spec. I'd say it is almost seventy percent of my time working with someone else directly. Hands on. Give and take. (Adam 02b:6)

Yes. Just this morning we were having a meeting with a customer and program managers about some things I have been working on. We were talking about ways to accommodate the customer and how difficult it would be, how much of my time it would take. (Brent 02b:6)

[What percentage of contact with people is verbal?] About seventy-five to eighty percent. (Charles 02b:6)

[Would you say your primary mode of communication is verbal?] Yes. I think so. Individual contact is probably sixty percent. Phone contact is probably thirty percent. Maybe mail is ten percent. [Are there any other ways you contact people?] Yes. Interoffice mail. I usually like to deal with people individually so there isn't any miscommunication. They look at me and talk to me. (Daryl 02b:6)

[Of the variety of things that you do, could you give me a percentage of time you spend working with people?] It varies, depending on the activity and that depends very much on what is going on at any given moment in the design cycle. Currently this year, it is stare at the...tube here a lot. You have people interacting with questions. They come in and talk, then they leave. They have to go out and find a solution to it. So there will be a lot of interaction. Then when they said we have to rebuild the [product], that is something the computer does and it will take us about a week of running them on separate computers. It really is hard to predict. Actually, I kept track, you spend about fifty percent of your time dealing with other issues which is mostly dealing with people on other subjects. (Earl 02b:4)

Mainly I interact with the group of people I work with. [Is it primarily talking things over?] Yes. It is because the software is so huge and complex and each of us have dealt in different areas of it. (Freddie 02b:6)

[The kinds of interaction you have with people are visual, you talk to them a lot, you write documentation. Do you send a lot of e-mail?] Yes, I send a lot of memos by e-mail. A lot of times just a quick message. Even more than what is done through e-mail, I do over the phone because I get a lot quicker response. They have voice mail and a lot of times they will respond quicker to voice mail than e-mail. Or a lot of times if there is someone I need to talk to that is close, instead of calling, I'll just walk over there. [Of all of the ways you communicate with people, what is the primary way?] Like talking? Talk then draw pictures. (Jeff 02b:6)

Communication also occurred through visual means during discussions held by

programmers. Talking about an intangible product of one person became easier with the

use of visual representations for explaining the flow and content of the software being

developed.

[When you have to talk to people about presentations or things you have to do in your programs, how do you communicate things to them?] Mostly visually. Whenever we talk with each other, we do a lot of our talking on a white board, in a cubicle or a conference room. They are needed. The best way to show some software flow or whatever is by a diagram on the board.(Jeff 02b:4).

[What would you consider problem-solving skills to be?] I have found it is really important to think about your design and try and get an overall big picture of what you are trying to do. I wish I would have had a little bit more of the technical part of software engineering. I had really a superficial look at the methods. Here is a waterfall, it has squares and boxes, and you use GATT charts, and you have design reviews. I guess I wish I had learned more about patterns in software—how to actually design a class or a template. It gets more involved than just draw pretty pictures and diagrams that show the flow. You really have to think about how everyone is going to interact with each other and how that handshaking is going to take place. I would have liked a more technical and in-depth approach to software engineering. (Freddie 01:4)

Visual representation of a product was used in both hardware engineering (schematics) and software engineering (flow charts). However, design of the product occurred through oral, written, and visual communication with other people to identify necessary components or features of the product.

Communication in all of its forms was essential to product development from conceptualization of the idea through production, debugging, testing, documentation, and implementation of the final product. These participants continually exchanged ideas and worked with people in a joint effort to solve problems. This cooperative process was a systemwide type of cooperative interaction among peers, managers, and customers to resolve problems.

Job Tasks and Visualization Skills

There were other skills related to performance of job tasks that the participants considered to be important. Those skills were described as the ability to think on abstract levels and to visualize.

[What kinds of skills are needed for your job?] Visualization is important. It is a wonderful skill.... It is good to be able to visualize where you are as well as have the language skills to know where you are. I guess I use a mix. It is nice to be able to encapsulate things as a single entity. That is another skill, abstraction. You lay a group of things together and say this is really one block or object.

[What is the most difficult thing about learning abstraction?] When new hires come I first notice that they are struggling with abstraction. When they are trying to communicate problems, they have to express it at the lower level of details rather than expressing it at the higher level of concepts. It isn't a good way to look at things. It takes a long time to go through all the details. It takes a long time to work though things. It is very exhausting work. By learning to abstract and going to a higher level concept it makes work easier and you can solve a lot of lower level details. (Brent 01:4) [Is visualization an important skill?] Absolutely. Yes. I guess that is where I though the math that I learned was so helpful. I had teachers who did try to get you to visualize. What does the sign of x look like when you graph that out over this area? We went into *Mathematica*⁷ and saw these wild pictures. I had an excellent linear algebra teacher who taught us how to use it to solve a networking problem. If you have all of these computers networked, how is the flow going to go and where is the critical path. In math it seemed like it was similar to solve a math problem and a computer problem. The steps you have to go through to solve them are the same. In math, if there is some way you can visualize it, it helped tremendously. (Freddie 01:4)

[Is it correct to say then to be a modeler, you would need the ability to visualize?] Right. Absolutely. A lot of the questions I was asked when I was hired on for the job were questions relating to how well I could visualize something. (Irene 01:4)

[What kinds of skills are important for a person learning to do graphic programming?] Able to visualize things in three dimensions. When I was in school, my first major was in art. I switched majors but I think my skills as an artist helped me in computer graphics because a lot of times when I can't explain things verbally, I'll explain things on the board. I'll draw it on the board. That's me. It lends well to computer graphics if you are used to visualizing things on the board and also in three dimensions. That helps you in programming and computer graphics. Not only that, but using the math that uses three dimensions like analytic geometry and trigonometry and matrices that you can transform into graphics. You usually transform it through a matrix so you need to understand that stuff. You don't have to have a real strong math background. You don't need to know calculus. (Jeff 01:4)

The ability to solve problems involved a variety of skills. The participants who programmed software suggested the ability to visualize and conceptualize information on a more abstract level was a valuable skill. The software engineers used visualization during the design phase because it allowed them to internally conceptualize the task and determine how to organize the code (e.g., critical path). Mathematical models also had great importance in the creation of figures or surface features of three-dimensional objects for the graphical user interface (GUI) software. These may be the skills that need to be taught in any profession that requires manipulation of information or products that are intangible.

⁷ Mathematica is software that transforms mathematical information into visual images.

Innova was apparently aware of the value of visualization in completion of job tasks and actively recruited individuals with this ability. It is uncertain if the abilities to abstract and visualize are skills that can be taught to all students, but these abilities may be skills that promote success in people seeking careers in engineering design jobs.

In summary, the daily job tasks involved actions requiring the ability to communicate through oral, written, and visual methods in order to solve daily job task problems. This created a need for a variety of job skills such as the ability to visualize, abstract, and organize information into a communicable concept.

Miniaturization was changing how hardware engineers worked—from working with objects they could see and manipulate to working with that which was too small to see or manipulate. This process was creating a need for new methods and tools to create or test electronic components. The following findings indicate the types of software being used on a daily basis in the performance of job tasks.

Software Tools

At the level of everyday tasks, participants were asked what kinds of software usage skills were important to have in order to be considered "computer literate." One hardware engineer commented on the need for engineering graduates to know how to write software programs rather than "hack" at code:

You need to be able to build your own tools in some language. Some engineers coming out of school don't fancy themselves as programmers. It doesn't occur to them to write software. They just keep doing repetitive tasks and will keep doing them for years until finally their manager asks why they are spending so much time doing that. Someone will kick them and say write some software to get out from that kind of thing, but they don't fancy themselves as programmers. It is a kind of hack programming. You don't sit down and do a top down analysis. You hack something together to get out from under a problem. To me that is what engineering is about. You don't have to document them until someone else wants to use them. (Adam 01:4)

Participants thought that employees working at professional levels also need to know how to use the "killer apps" in performance of daily tasks. They stated:

A word processor is necessary. Usually it isn't that they don't use a word processor very well as much as they don't write very well. They can't convey concepts very well. . . .Spreadsheets are not taught to them and you may wonder why you would ever need them. But you look around this company and spreadsheets are everywhere and engineers are using them. When I travel, I come back and fill out a travel report on a spreadsheet. Everyone needs to know how to use a spreadsheet. I even used a spreadsheet once to do a simulation of a digital circuit. I think they made a mistake to leave out the killer apps as they are referred to, word processing, spreadsheet, database.

Understand the killer apps, certainly word processing, spreadsheets, presentation stuff. You almost insult an engineer when you act like he needs to be trained on a word processor or presentations. Well, that's obvious. There is an attitude thing there that you teach the business people that. [Why is that?] I don't know. I think engineers kind of view this is what I want to do, this is the core, and that is fluff. I don't need that. (Adam 01:4)

I think there are some things that are important. You can make a lot of use out of spreadsheets, but you have to know what they are. When I first got hold of one, I didn't have any idea of what it was trying to do. I think some basic knowledge like that would be useful. I can guarantee that no matter which one you learn, it will not be used any place you try to use it. They almost always want the other guy. There is almost no way, at least I can't, become proficient in two or three of them. (Earl 01:4)

Software engineers stated a programmer would need to know how to program

to be computer literate. However, the participants also stated the ability to use basic

operating system commands was important. This skill was needed to set up operating

system software in the electronic environment:

[Computer skills would basically be understanding what?] Everything that goes wrong when you are trying to get set up. Which would be how to configure it, how to set up your autoexec and how to set up your PCI [PC interface]. Also there are a lot of different tricks. Some programs require a certain amount of memory, some eat a lot of memory. By changing memory locations, you can get around that. But a lot of people don't know how to do that. (Daryl 01:4)

Today you really have to know something about two of the operation systems. In the PC world, you have to know MS DOS. You have to use UNIX.[Why is UNIX so readily used?] I think UNIX became widely accepted because it was essentially public domain and easy to get.

... [What other kinds of things would be important to understand?] Things like memory swapping... You need to understand how the computer uses the different kinds of memory and the impact it has on access speeds. (Earl 01:4)

As a minimum, definitely you shouldn't have any hesitation at sitting down to a computer, turning it on, and being able to maneuver around in the system,
like from drive to drive and being able to find executables or the compiler you need. That's kind of like knowing how to use a hammer. (Freddie 01:4)

You have to take files and manipulate them. For example you take files out of Excel and make them into different formats—fixed, comma separated, or whatever. I have had to do a lot of porting from VMS to Excel and back again. I've used Access because it is a very good tool for file manipulation between different kinds of formats. These days, this is one of the things you have to know if you are working in a mixed environment at all. (Heide 01:4)

Participants listed the traditional computer literacy items such as being able to turn on a computer, move around in the operating system between internal and external drives, find and retrieve data, and know how to use the basic software "killer apps" (i.e., word processing, spreadsheet, database, and presentation software). They also believed people should know how to perform data management tasks such as writing documents in a word processor, use a database, transform data from one platform format to another (e.g., PC data file converted to a UNIX format), understand how memory operates and limits a computer, and move around in a networked environment.

Another skill mentioned was the ability to understand and to use multiple types of operating systems. The types of operating systems being used at Innova were *MS DOS*, Windows (X and *MS*), *Apple OS*, and UNIX (see table 4.5). Participants

		MS DOS with				
Participant #	UNIX	Windows 95	MS Windows NT	Macintosh		
11	yes			yes		
12	yes					
13		ves				
14		ves				
15	yes	yes				
21	ves					
22	ves			ves		
23	5	ves	ves	-		
24	ves			ves		
25	ves					

Table 4.5

believed the UNIX system setup was so complex that the best way to train or assist someone else with setting up a UNIX system was just to give the setup files to them (responses taken from Second Interview, Question 5).

Three participants used only the UNIX environment. Four participants used primarily UNIX and had another computer with a different platform (*Macintosh* or *Windows 95*). Three of those participants used *Macintosh* computers to draw graphics or read documents. Two participants used only the *MS DOS/Windows 95* combination operating systems. One person used two different computers, one with *MS Windows 95* and one with *MS Windows NT*. Although the *MS Windows NT* platform was designated as the operating system the company would be using with the new simulation software being developed, only one of the participants at the time of the study was developing software for that platform.

Seven participants had to understand how to effectively use the real-time operating system found on the simulator systems. A real-time operating system is a more complex operating system than those normally found in academic settings. This is an explanation of a real-time operating system:

You can't be doing quite a few tasks in the background, you can't be sitting there and waiting for something to render. You can't sit there and watch the pixels to be drawn on the machine. Things are supposed to happen as if it were actual reality. The simulations systems we program and design, when they are out there using them in a training simulation situation such as a fighter pilot turns the stick to fly over this way, that database has to come up and be rendered as if he were actually looking outside. The radar picture has to be able to do the same thing. It has to be able to look at the terrain and the features where he has just turned to or to come back. It has to act as if it were in the real world. I didn't realize until I got here, that was a big trick. You see on TV shows where they use really nice computer graphics and in a lot of movies now, beautiful computer graphics with very smooth motion. The rendering looks almost realistic. I would guess that in ninety-nine percent of those cases, what you see took days for a computer to generate, to put together, for them to record to film. It's not anything you could sit down and see in a simulator cockpit. Our simulation databases look a little hokey. It's not smooth and beautiful and picture perfect because to do it in real time, so far, we don't have the computing power. Or no one wants to pay for it yet. (Freddie 01:3)

Understanding of multiple operating systems for a variety of computer platforms was a required skill for these participants. The two primary operating systems used by Innova engineers were UNIX for the Sun Workstations and the realtime system used with the simulation software. However, Innova was moving toward the *Microsoft Windows 95* operating system provided on PC platforms. This transition would create a situation where some of the software engineers would have to have three systems and three computers to write code on: UNIX with the Sun Workstation, realtime with the mainframe simulation system, and *MS Windows NT* with a PC. Proficiency in both complex and simple operating systems allowed the employees to move between the operating systems used to develop software on all possible combinations of hardware systems.

In summary, important considerations in software usage skills were the ability to use common software applications to perform daily tasks (i.e., word processing, spreadsheet, database, networks, and utility programs) and an understanding of multiple operating systems and associated software programs. The following section provides information on the skills required for use of computer hardware tools.

Hardware Tools

Knowledge of computer hardware in traditional computer literacy definitions is restricted to understanding how to turn on/off the machine and perform simple operations such as keyboarding or use of a mouse to input data (Amini 1993; Anderson and Collis 1993; Day and Athey 1985). On a general level of work, these were sufficient skills. Participants reported that Innova provided personnel who specialized in setting up the assigned workstation equipment (First Interview, Question 6). If any modification of hardware was required, a network administrator would respond to a work request and perform modifications to the computer. Also, the physical plant

personnel would rearrange the furniture or hardware upon request. Participants were not required to understand how to set up their own hardware equipment or work areas. (See additional findings in the section on arrangement of the workstations.)

However, the participants had to know how to modify the image generation system hardware that they used to test or demonstrate their product. This was explained by a participant who found it necessary to set up a system to demonstrate her software:

But in this most recent software assignment which is a workstation renderer that we sell to customers, we have a system down on the test floor, and it has been more important for me to understand how to set that up as far as plugging in things here and there with all of the devices attached to it—the VCR, the videodisk player, and the video mixer. These are some of the pieces involved in the hardware that go along with this particular piece of software we sell. It has been more important for me to understand how to connect all of that up in case I'm someplace where there is no one to ask, so I have to know how to do it. But I have been able to get by this far without knowing a whole lot about workstations and how to set them up. (Irene 01:3)

Understanding how to set up the hardware at a workstation was not critical to performance of daily job tasks. However, understanding how to change around components in the image generation system or on a demonstration unit was critical to testing or demonstrating the product. Therefore, it was inevitable that the participants would have to know how to effectively modify computer hardware or cable the network between computers in order to test products. Adam indicated that understanding how to cable a network was an important job skill for modifying the shared workstations:

I think it would be useful for engineers to know about networking. Every time I turn around, I have to go back downstairs and reconfigure our network. Our product is network-based and the tools we use to develop them are network-based. You start out with everything on the network, your tools and your product. Eventually you settle out with just your product running its own network. I'm surprised at the number of people who are confused about what's going on. But there is no training on that and nobody here telling them how to do it. You sort of pick it up word of mouth. That tends to breed a lot of misunderstanding. A good example. If you are doing ethernet communication, there is point to point and something called backbone. There are different types of cabling you have to use when the configuration changes. It would make sense to me if people would understand what to use in the different configurations. They need to know cabling and the operating systems. (Adam 01:4)

Understanding how to cable the network was one aspect of competence in

usage of a network. Participants would often have to access other computers linked to

the network to either download information or use the CPU for processing information.

Simultaneous usage of several computers on the network was a basic part of the

workplace strategy at Innova. Being able to access multiple computers and knowing

the name of the computer being accessed were equally important:

This process is actually running on this machine. What you do is sit here and say, well, this one just finished its work, the CPU level had just dropped. The machine has two CPUs and somebody was using one of them. So you could start a job there. I'm really working from here but I'm using workstations all over.

[Are those workstations at individual's desk or in test centers or where are they?] This one is out in the main area you walked by. This one is over the wall, over there. This one is out in the main area, so is this one. I have access actually to the ones on everyone's desk or in various places around. I can really get to anybody who is on vacation or not in their office or not doing much. For example, the guy across the wall there likes to run stuff on one called "Dinosaur" which is at the other end and sits in someone's office but the guy isn't a real power user of it. So it has a lot of free time. What you are really interested in this particular job is how much memory they have. So you hunt down the machines that have fairly large memories and don't get much activity, and use those. (Earl 02b:4)

In order to access the remotely positioned CPUs, the "name" of the workstation had to

be determined and permission to access the machine negotiated.

To find out the memory, you actually have to ask the system administrator. He sent out a list which listed a bunch of them that had large memories. There's one that's called "Confusion." I don't know who makes up these names. "Confusion" is a two processor machine with a gigabyte of physical memory so it has lots of RAM in it. That's a good one. This one—[indicates icon of a machine on screen]—you almost never use this one. "Conrad" is a 256 megabyte machine but it has two processors. So if you only get one of the processors and about half the memory, you are about like this one, it is "Typhoid." It [Typhoid] has one processor.

[That is the name of your unit?] Yes, "Typhoid" I didn't name it.

[You didn't?] I have no idea why we named it after a killer disease. [OK.]

You have to look at these. "Conrad." Here we have "Dilbert," "Pudding," "PASCAL," "Dogbert," "Lizzy." [Who names these?] I don't know. I assume we have some perverted namer.

[Like a Network Administrator who would typically set them up and name them?] Usually when they get a machine, they pick somebody, usually the guy who's buying it or it originally goes to, gets to select the name. That gets sort of coded into the network and it is impossible to change them. For example, the guy who named "Typhoid" went to work for [ABC] and left "Typhoid" here. But he named his new one down at [ABC], "Typhoid." The guy that has "Dinosaur," when they put it in his office he named it "Dinosaur" because he's sort of into dinosaurs. A guy down here a little ways has a computer named "Beef." His family does beef ranching. Some of them there is no excuse for, like "Typhoid." We have "Tire-Track." There's "Fallen Arches" that was named after Arches National Monument. The guy over here has "E Point" it is named after Exclamation Point which is a climbing path here someplace, he's a climber. Yeah, the names are weird. . . It's obscure. It is whatever somebody is interested in when they get the opportunity. But there are literally hundreds of them. You can get at any of them if you can find out the name for it.

[So if you don't want someone on your station, don't tell them it's name?] Exactly. There are a couple of ways to start a job. If you start one that is just ugly, it will acquire all of their memory and run their CPU and they wouldn't be able to do anything. But if you tell it you want it to run "nice" then it gives their console priority so they don't really know you are there.

[How do you know when someone is on your system? Your system slows down?] Primarily. See this CPU meter down here. This is "Typhoid" down here. It will start going up and you aren't doing anything here and you go, "Ah, somebody's on that thing."

[Is there a protocol within the department for using somebody else's machine or is it cultural?] Yes, if you are really nice you ask them. If you are really interested in getting some work done, you just do it. Almost everybody will say no. You know, it is just say no. You usually like to find out what somebody is doing. For example, we have a guy up here that has a machine that's quite powerful and he currently is doing a lot of text editing and [text-editing] isn't a very heavy user of the machine. So we can use that. If you can find out, some people will be nice. It is fairly competitive to find high power machines that will do the jobs. If you find some that are kind of a secret—like there is one called "Serenity" that nobody knows were it's at but nobody ever uses it.

[S-E-R-E-N-I-T-Y?] Yes.

It is a fairly good machine to run on because nobody actually physically knows where the machine is. Nobody apparently uses it. We assume it is tucked off in somebody's corner someplace. That is a closely guarded secret.⁸ (Earl 02b:4)

Job tasks required use of other types of technologies also:

⁸ The names of the machines were changed to pseudonyms. However, the researcher did not have a list of the names assigned to workstations; therefore, the pseudonyms used may unintentionally be names of workstations found at Innova.

[I noticed the other day when I was observing that one of the people in your work group got a *Polaroid* camera out and took a picture of an image on the screen. Why was that?] They [the customers] wanted the picture painted in different kinds of modes. They were having us do a mode totally differently than we ever have. I was playing around with the pixels in the software to get it to do this and it was missing a big part of the picture. So he would go back to the regular mode and then the new mode to see what was missing. He wasn't able to do it quick enough, it just wasn't easy enough, so he got the camera out and took a picture of the screen to see what was there in the two modes so we could see what was missing. It helped a lot. (Freddie 01: 6)

A hand-held calculator also provide to be a necessary tool:

[I noticed you had your calculator out. Is that because the system doesn't have a calculating system you can get to?] It does. . . . My [hand-held] calculator, I'm very accustomed to it rather than using a mouse to click on everything. This [UNIX system] has three different calculators you can bring up. In order to use all of the functions we use, you would probably need all three of them. We do conversions into hex and hex into binary or something like that. We use a lot of angle calculation and sin, cosine.

[So it is just easier to use your hand-held calculator?] Yes. I like to use it a lot at the [simulation workstation]. The workstations have calculators but the [simulation workstations] don't have calculators. (Freddie 02:4)

The sophistication of the workstation did not ensure that the participants could

use the computing system to perform all necessary tasks required for an assignment. In

one instance, multiple systems were accessed to utilize computational power. In another

instance, a Polaroid Camera provided images the programmer used to modify a graphic

image and, another time, a hand-held calculator provided necessary numeric data for

computation because a computer-based calculator was not available or it was not easy to

access.

In summary, job skills related to the use of hardware tools required participants to understand how to set up and effectively use computer hardware and the computational potential of networks. The participants also needed to be able to connect various pieces of peripheral equipment. Participants understood and used alternative forms of technology when necessary (e.g., a hand-held calculator and a Polaroid Camera).

Training Other People to Use Tools

Computer literacy has been defined in terms of what a person needs to know to operate computers (Anderson and Collis 1993; Day and Athey 1985; Hofmeister 1984). However, it was determined during the interviews that the participants had to provide documentation on their products and occasionally orally assist others in understanding how to use hardware and software. Therefore, another area of functional skills appears to be communication of information or training to other person.

Participants were asked if they ever had to train people to use their software products. The participants indicated that most of the training occurred between peers, but the participants also trained customers how to use of the products.

I teach customers and people in the company how to use [our proprietary software]. [What is the most difficult thing people have to learn, in use of software?] People have to overcome the sense of "magic" in computers. We see things that are displayed in front of us on computer screens. Most people don't understand how temporary things are on the computer screen. They don't quite understand what they are looking at is a delicate instrument that if something goes wrong, this could cause some of the electrons to go somewhere else. They have to learn to adjust their habits to prevent mistakes from happening, like saving their work where to learn to play its [computer] game. (Glen 01:5)

I have, but very minimally. I've had to show people how to use an application, mostly with the system I handle. I have a sheet that I give them. It tells them to go here, you do this; when you want to back out, you do this; when you want to change screens, you do this. The rest is pretty self-explanatory. (Heide 01:5)

Occasionally that does come up. I've never had to do formal training. There are people in my department who do that. One person in our department is a trainer, and she has people who come in, and she has to train them to use our software and the concepts of how to do database designing and modeling, like I learned when I first got here. I've had to train people on an informal basis when I've written some software. I've had to train them how to use it and what it is doing so they understand the concept behind it. (Irene 01:5)

Yes. The tools I write, I train people to use it. [Do you give formal classes?] No. I have done formal classes with a company I worked for before I came here. But I haven't taught any classes here. [Why would you need to teach people about the tool?] They learn better if they are told. All of our tools have on-line documentation and written documentation. (Jeff 01:5)

Formal training classes were handled by an individual specified by the company. That individual was a trainer and had a specific job function for training people to use the company's proprietary software.

The informal training of fellow employees was a process of peers helping peers. This approach to training appeared to be based on job experience rather than expertise in training people.

All of the engineers wrote explanatory documentation of products they had designed. Documentation appeared to be based on functions or features of the product. The participants did not indicate they had any formal training on how to prepare documentation used to train or inform people.

There were people at Innova whose job was to provide a training session to external customers or in-house personnel about the use of proprietary software and hardware. However, the participants also provided informal training on how to use software to fellow employees and sometimes to external customers. All of the participant trained people on an informal basis or created documentation (on-line or paper manuals) for software products.

There were several types of situations where training was required. Those situations were (1) formal training in a class setting to teach people to use products, (2) creation of on-line documentation or paper manuals to explain product features, and (3) informal training in the work setting to teach people to use hardware or software.

The participants did not show customers how to set up image generation hardware. That activity was a specific function of project engineers (none were included in this study).

In summary, participants needed the ability to communicate information on use of software to customers through informal training or documentation. However, the participants did not have to train customers to use hardware. It was ironic that they had to learn to use networks and peripheral devices but did not teach each other or customers how to perform those tasks.

Summary and Discussion of Tasks and Tools

Effective usage of computer hardware and software tools was a process at Innova. It was a process because it consisted of a series of continuous actions, operations, or series of changes taking place in a defined manner over a course of time.

Job skills related to use of hardware and software tools at Innova were defined as being able to:

- Turn on a computer and use common, commercially available software applications (i.e., word processing, spreadsheet, database, and programming languages).
- Understand the common business software applications well enough to utilize software functions to solve daily problems.
- Understand and be able to use multiple types of operating systems and networks (i.e., UNIX, MS DOS, MS Windows NT).
- Use oral, written, and visual methods to communicate with other employees or customers.

Participants did not need to understand how to set up hardware in their workstations because the hardware within the company was set up and maintained by network managers or the physical plant personnel. However, those participants whose job responsibilities included debugging and testing products had to understand how to set up computer hardware in the test areas. They also had to understand how various types of equipment were connected to their image generation systems. The participants indicated they did not learn how to set up hardware while attending academic classes but rather through self-instruction and trial and error. The primary method identified in the literature review for becoming computer literate was to attend instructor-led, classroom-based training. However, the method reported by the participants to gain their computer skills was through self-study and applying skills on the job. Applying skills on the job occurred through both selfinstruction and peer tutoring.

When considering the state of constant flux of new technology within Innova, it is understandable that the employees would attempt to learn how to use a new product or software either by self-instruction or from peer tutoring. Because employees need to stay current with new technologies in the workplace, it would be valuable for employees and students to be taught learning strategies to promote effective selfinstruction. It also appears that technology-based professions need skills to promote effective oral, written, or visual communication to a wide range of people (peers, managers, customers).

An important change that was driving the integration of new types of technologies and software into the Innova workplace was a move toward further miniaturization of their hardware components. Although many of the hardware components already existed as very large scale integrated circuits (VLSI) that could not be seen with the naked eye, the company was moving toward even greater density of even small components on the same size of boards. This created a situation that forced the engineers to use different equipment to design components and detect problems than they had used in the past. The miniaturization process was causing the hardware engineers to move away from old design skills and troubleshooting skills toward new conceptual and visualization skills that relied on computer software for design of products and problem solving. This was a type of problem-solving skill that required logic as well as the ability to visualize and conceptualize an idea so that the idea could be emulated by software.

The skills and knowledge associated with job tasks included both the traditional computer literacy topics (e.g., how to use basic hardware equipment, use of software, and logic skills) and new computer tasks skills (communication, visualization, conceptualization of ideas). The following section provides findings on the physical environment where the daily job tasks were performed and the how tools of work were used.

Workstations

This section of findings explores the environment in which computers are used. The general guiding question for this section of the study was, "What do people need to understand about setting up their work areas to promote health and safety?" Workstations contain the tools of the trade—computers. Therefore, job skills should also include an understanding of how to safely use the tools. The findings related to skills and knowledge associated with safety were grouped into data areas identified from the literature review: (1) understanding ergonomic principles, (2) workstations design, (3) ergonomic assessment of the workstations, and (4) prevention of injury.

Understanding Ergonomic Principles

The following findings are related specifically to ergonomic factors and the individual participant's understanding how to adjust their work area for their individual physical dimensions. The data for this section were drawn from the Ergonomics Concerns Quiz administered after the second interviews and from responses received during the second interviews.

Ergonomic Concerns Quiz.

After the second interviews had been completed, an oral quiz was given to determine the general level of the participants' expertise in ergonomics. The quiz

consisted of a picture of a workstation with fourteen numbered items shown (see Fig. 4.1 and Appendix H for correct response to each item in the quiz). The participants were given the quiz sheet and asked to define or describe the items they knew. No previous mention was made to the participants about testing their knowledge of workstation components. The results are reported here to establish an understanding of the relatively low level of participant expertise in ergonomics.

The following summarize what the participants believed to be correct about the items on the quiz:

- Viewing distance. Not too close, not too far, comfortable to prevent eye strain. Two distances were mentioned: 18" and 20".
- Reach area. Participant replies suggested they had to be able to reach the mouse, keyboard, and telephone. One person indicated a reach of fifty degrees in front of him. One person thought it was the same as his vision area. Two people could not define reach area.



Fig. 4.1. Image Used in Ergonomic Concerns Quiz

- Head posture. Fairly straight and forward, not looking up or down too much. Three people could not define head posture.
- Shoulder posture. Not slouched. Most indicated they tended to slouch but thought they should not. Two people believed their chair was the key to good posture. Two people could not define shoulder posture.
- Arm posture. The arms should be at the side of the body with a ninety degree angle at the elbow/forearm bend. Two people could not define arm posture.
- Back support. The chair should provide stiff support for the back. Three people mentioned having lumbar support as important. Two people could not define back support.
- 7. Chair adjustability. The chair should have adjustability for seat height and adjustability for the position of the back of the chair. Participants thought chair adjustability was important to provide the correct height for viewing the monitor. One participant was concerned about the ability of the chair to roll. One participant said the height of the chair should be sufficiently high so the back of his legs were not being creased when he sat down. One participant knew how to adjust a chair but did not know the recommended adjustment for his physical height. Two people were concerned with the ability of the chair to rock.
- Foot position. The general response was to have their feet flat on the floor with room to move them without hitting cords or other obstructions. Four participants could not define foot position.

- Legs. Three participants suggested the legs should not go to sleep while seated. The other participants guessed the legs should be bent at a ninety degree angle.
- 10. Angle of forearm (at elbow). The response was to have a ninety degree angle at the elbow with arms and wrist straight ahead. One participant could not define the angle of the forearm.
- 11. Keyboard. The most frequent response was to have the keyboard close enough to reach and at an angle to allow the hands and wrists to be straight. However, several people indicated they placed their wrists on the table when using the keyboard (one removed a wrist pad in order to do this). One participant mentioned that keyboards are all different and not standardized. One participant mentioned there are split keyboards available. Two participants did not make any statements about keyboard positions.
- 12. Work surface area. Participants indicated this was the area where they placed their documents. Three participants indicated they placed their document between the keyboard and monitor. One participant placed the document on top of the mouse pad but indicated using the mouse got in the way of seeing the document. One participant indicated height adjustment was important but did not know what height. Four participants could not define work surface area.
- 13. Field of view. Two participants indicated the field of view was related to what was seen on the monitor. The other participants equated field of view with viewing distance to the monitor.
- Line of sight. Participants generally indicated it was the angle of vision straight ahead or a slightly downward-looking angle from the eyes to

where the participants looked at the monitor screen. The reported preference was to start at the top of the screen and move the eyes downward to view the screen rather than tilt the head upward to view the screen. Two people mentioned glare on their monitor as a line of sight issue. One participant could not define line of sight.

In summary, eight of the participants made an attempt to explain each item on the quiz. Two participants generally had no knowledge of the items. The items the participants were most knowledgeable about were arm posture related to elbow angle, chair adjustability and back support, and the keyboard. The one item they were concerned about was shoulder posture because they knew they slouched but believed they should not slouch. The items they were the least knowledgeable about were leg and foot positions and field of view. Although the participants did not know what the field of view was, they had opinions about the proper distance to place the monitor and at what height their monitor should be for comfortable viewing.

The participant responses did not indicate a technical knowledge of the items on the quiz. However, the responses generally indicated participants had explanations based upon experiential knowledge from working around computers for many years.

Setting Up a Workstation

Prior to the Ergonomic Concerns Quiz, the participants were asked if they had received any prior information or training on how to set up a computer workstation. The participants' responses reflected the typical training method—self-instruction:

Well, informally. By word of mouth. Someone mentioned to have the screen at eye height and stacking it on top like this. When we first got the workstations, they said for us to just put them out there and someone would come around and hook them up for us. Actually I strung my cables myself because I wanted them this way. But as far as installing the computer and getting it running, there are guys whose job it is to do that. (Brent 02:4)

No real training. I've asked people a few questions here and there. (Freddie 02:4)

No. Well, I take that back. Just this morning, I looked through this booklet from Compaq that talks about what you should do for your vision and your wrist and for everything. I looked through that this morning. It is the only thing I have ever read that has a comprehensive list of do this, don't do this. It is all pretty basic stuff, I mean. [Did you learn anything new from it?] No. (Heide 02:4)

No, I can't say that I have. Not anything formal. You have word of mouth. People have their wrist rests. I don't have one just because I've never been—I don't know I should be concerned about it. But I've never gone out and made the secretary order one [a wrist pad] for me. There are people who have mouse rests and wrist rests. They do all of the precautions. They make sure they are at the height they are supposed to be so their arms are straight. Basically by word of mouth you hear what the precautions are. I can't think of any seminar or formal training I've been sent to, to learn those things. (Irene 02:4)

Other participants attended classes or seminars on setting up workstations.

They were aware of some principles of ergonomic design.

Yes, in an ergonomics training class. [In your ergonomics training, I assume it dealt with setting up your workstation and reducing injury.] Yes and making it efficient. (Charles 02:4)

We had a class on it and it was really generic and pretty basic. I honestly can't remember and I honestly can't remember most of what went on there. Most of it was on carpal tunnel. [Related to how to minimize carpal tunnel?] Yes. (Daryl 02:4)

You mean functionally or egonometrically? They did have a guy come in that was an ergonomic specialist who worked for an office furniture place. But he came in and talked to some of us, I don't know if he talked to everybody, but I got to go to it. He talked about heights and how you wanted the keyboard. He did not believe in arm rests, and he didn't believe in leaning back in the chair. He liked these chairs, you know, where you sit forward. It's supposed to be good for your back. Could be. It didn't look that good. He talked a lot about how to physically set it up if you were having problems. And otherwise how to set up the whole thing. (Earl 02:4)

The previous company I did. I don't remember getting any training here on how to set up a workstation. [What do your remember learning?] How to set up a chair, how to sit right, how to set up the tilt of a computer and keyboard and my mouse and my wrist and how to sit. Not like this, but up like this. [Down is more comfortable?] It is, but I get tired of sitting like this (Slouched.) so I sit up but then I'll slowly slide down. [You need some Velcro.] I know. I need a seat belt to keep me up the way I should be. (Jeff 02:4) In summary, one participant had formal training from an academic discipline related to the engineering of products. The other participants had attended a seminar or received information from fellow employees on how to arrange hardware and computer furniture. None of the participants had training on how to assess the risks related to computer use or how to correct potential causes of injury.

The participants' responses indicate that the initial arrangement of the work area was done by the department network personnel, but the participants later rearranged the various components the way they believed to be the best for themselves. Through a question asked of the management personnel at Innova, it was proposed that the network personnel depended on the physical plant facilities personnel to implement ergonomic standards. This was not verified with the network personnel because no source was available. According to the sources at Innova, the first line of defense in the company for reduction of injury to employees was correction of possible problems in the physical layout of employee workstation areas. However, there was not one resource that actively monitored the work areas to identify potential problems. The work areas were set up and left for the individual workers to either change or request changes if needed.

Workstations and Day-to-Day Reality

It was therefore assumed that at Innova, the employee workstations were the areas most likely to be monitored and corrected by the company because components of workstations have been identified as a source of potential injury (Bergqvist et al. 1995; Carter and Banister 1994; Grandjean 1984; Jaschinski-Kruza 1988; Sauter and Schleifer 1991). Therefore, the participants were asked to explain: (1) why their work area was arranged the way it was and (2) how the furniture or equipment was adjusted for their individual physical dimensions. The OSHA Assessment Form was also used

as an additional source of uniform data to evaluate each work area for furniture, work habits, and training.

There were two actualities in arranging the workstation areas. One actuality was the standard configuration that the plant facilities imposed on the work areas and the other actuality was the way the participants rearranged their workstations after they moved into that space.

Suggested Configurations

The manager of plant facilities at Innova provided two different floor plans for standard workstation configurations. The floor plans were used as a guideline by the physical plant personnel to set up workstations because there were no trained ergonomists assigned to evaluate the placement of the equipment nor the work patterns of the personnel.

The floor plan for the workstation provided by the Herman Miller furniture company extended the computer work area into the center of the work area module. The floor plan for the computer furniture provided by Steel Case had a specialized corner unit that placed the computer in the corner area of the work area module (see Fig. 4.2 for both plans). The presumed guiding ergonomic principle in the plans was to centralize the computer equipment to allow more efficient wiring; however, it would also tend to put employees in closer proximity to each other and reduce privacy while increasing background noise. This increase in noise and reduction of privacy was observed by the researcher and reported by the participants during their second interview.

Actual Configurations

The participants were asked why their work areas were arranged in the current configurations. Some responded that the work area was the way they found it:



Fig. 4.2. Generic Floor Plans for Work Areas

Mostly because this is how the office was when I got here. (Adam 02:1)

Well, actually the desk and bookcases were arranged this way when I got here. At first I thought I'd like to have the desk where my workstation is facing perpendicular to the way it is now so I can be sitting at it and facing the doorway. It feels strange to have my back or side to where the door is but the outlets here don't allow that. I've become used to it. I like it. It seems a little bit more open. When people come in I don't have a desk between them and me. [Other than changing the desk, is there anything else you had to get used to?] No. Not really as far as the arrangement of the furniture and bookshelves. (Freddie 02:1)

It is the way it came. I took this corner shelf out because my monitor wouldn't fit correctly. That is the only modification I have made to my work area. Otherwise it would have pushed the monitor screen out too far. (Jeff 02:1)

This is pretty much the standard, as far as the desk being an "L" shaped standard cubicle arrangement. I tend to like the workstation in the corner because [the keyboard tray] moves in. Obviously this wouldn't fit under here [the keyboard tray]. I've had offices where I've had the workstation set up on the table. That works fairly well too, especially with glare from the windows. That is the worst problem I have with the workstation being set up here in the

corner. I have to keep the blinds shut in the morning because there is a lot of light coming in. Other than that, I like having counter space on both sides. I find that useful. I like to spread papers out and have things accessible to me when I work on projects. (Irene 02:1)

Other participants indicated they arranged or rearranged the work area to make it

more efficient or to fit their individual preferences.

I wanted to be able to face out toward the door instead of having my back to the door. I like to approach it as having my terminal here and looking out in this direction. Most of the rest of the cube was sort of decided for me. In my other cubicle I had my monitor in the corner. The drawers are in the way to put the tools on this side, and I couldn't put the drawers here because they were coming out under the desk. There weren't really that many options rather than being completely up against the wall. (Brent 02:1)

With my computer on one side and my desk on the other because some things I do at my computer, and I want a lot of work space. . . . I put them across from each other so that I can spin and get to one or the other quickly. I added the extra table there just because we like to accumulate, and it gives me another place to pile...[Did you arrange this area yourself] Yes. (Charles 02:1)

It's probably not the preferable way but it is probably about what fits in the cubicle and where the data lines come in really dictate where my terminal is and computer is. Where the phone lines come in dictates where my phone is; however, I have it stretched a little. I wanted it so I could swing back and forth from my desk to the computer. [How deep is that monitor?] I don't know. It's really big isn't it? I could have gotten by with a smaller monitor, in fact I did have a smaller monitor, but this was available, so I thought I'd try it for a while. (Daryl 02:1)

Based on the small size of the work area, I had to design it so I could use both of my main workstations easily and effectively with a minimal amount of transportation between the two sides. (Glen 02:1)

Two participants rearranged their work areas because they were conscious of

needed accommodations for their unique physical requirements.

I have the corner unit which is bigger. They are logical places to put the computer. I have it lower because I'm trying to get the monitor height down. That is the reason I lowered it, not the keyboard. In order to do this, I had to put the computer under the desk. This is unusual, most people have them under the monitor. I was doing it so I could see with my glasses. (Earl 02:1)

With the bifocals I tend to want to get everything lower. A lot of people raise the monitors up. They are always sticking stuff under them to raise them up. Whereas, I'm going for lower if I could manage it. This one is constrained by the fact that the height of this table I have the computer [CPU] on, had to fit under this one [the one with the monitor] that can't go down any lower otherwise if I could get another two inches lower, I would. I've already cut the height of this table off by the way. The ergonometric guy they had come in here told us you should be sitting here looking straight ahead. But if I do that I can't see it, it is all blurry. I put it down lower so I can see it. And the last time I got a prescription, they suggested that I get glasses where I moved the bottom half to the top [reverse the bifocals to the top] but I haven't gotten around to do that yet. . . .They are talking about \$400 for a set of glasses so I haven't done it. (Earl 02:2)

Actually, the [counter] height is a normal height that most people use for table height. Before, in my old cube I didn't have a keyboard tray, so what they did was drop [the corner unit] way down and my keyboard sat on it. Everything on the corner piece was dropped down but that made it very inconvenient for writing. I had to write over here [on the raised table section beside the corner piece]. I couldn't put anything right in front of me. I really like putting things in front of me the way the keyboard is configured now. [The keyboard was attached below the corner piece on a pull out tray. This left the corner piece the same level as the rest of the counter top and allowed a clear area between the keyboard and the monitor.]

[I notice you also have a document holder. Do you use that also?] It depends on what it is. It isn't the kind of document holder that holds your place. I don't do that much with lines that I have to keep track of. I would use the document holder more if it had one of those. It depends on what I'm doing. It is about half and half [that I used the document holder or place the paper in front of me.] If it needs to flip over, I put it in front of me. (Heide 02:1)

It used to be you couldn't get a chair that raised and lowered enough so your feet could hit the floor. Now they do and that is nice. I still don't feel like what they do with the back of chairs is good. I haven't tried that many. Things are flexible enough now that most everything fits. If I have my chair low like it is now, I'm sitting in a hole for a normal sized table. If I can have my keyboard lowered down so it fits with the lowness of my chair, then that is fine. [Have you become an expert on chairs?] Not really. Before I got this chair, I used what I was given. It is a problem if the seat [pan] is too long. This seat was left to me by a lady when she left. It is the best chair I have had and she got to pick it out herself. She was probably five-feet-five. She picked it out so it would fit her better than any of the chairs we have ever had. A chair is a big factor. I got this one a year ago. [Is it easy to adjust?] Yes, you can adjust it up and down and also the back goes back and forth. And the company has these ugly things [foot rests]. Also, I have this foot stool. [How do you use that?] I put my legs straight out on it, like I'm on a couch and I relax on it. [Did you have that made for you?] Yes it was made for me from scraps. (Heide 02:2)

The ability to adjust the equipment, furniture, and work surface heights was important to the participants. They also reported that they needed space around their computers to allow them to write or place papers for viewing. Having a paper holder beside the computer monitor was not the preferred way to hold paper copy because the participants weren't performing data input. The interaction was from their minds to the screen rather than from a piece of paper to the screen. When the participants did refer to pieces of paper, usually notes or the handwritten path for locating a file, they placed the paper either between their keyboard and the monitor or on the table to the side of the keyboard. The following drawings show how the participants had their workstations arranged (see Fig. 4.3 and Fig. 4.4).

An analysis of the workstations provided the following facts:

- Four of the assigned work areas had two computer stations set up in the cubicle (participants 11, 15, 22, and 24), and only two of those participants used both computers on a daily basis (participants 15 and 22).
- Six of the workstations (participants 11, 15, 22, 23, 24, and 25) had corner furniture modules where the monitor, CPU, and keyboard were placed for work. These configurations were similar to the suggested floor plan of the Steel Case Company (see Fig. 4.2).
- One workstation (participant 12) used an "L" shape configuration similar to the suggested floor plans of the Herman Miller Company (see Fig. 4.2).
- 4. Three of the workstation arrangements of desks set across from each other because of the positioning of the available power outlets and size of the cubicles (participants 13, 14, and 21). These workstations were not patterned after the ergonomically designed floor plans used by the company.
- 5. Four of the workstations had keyboard trays attached to their tables (participants 11, 13, 14, and 23). Three of those keyboard trays were present to allow the participants to hide the keyboard under the desk when it was not being used. Only one of the keyboard trays was being used to lower the height of the keyboard. The other participants had the keyboards





Fig. 4.3. Arrangement of Work Areas for Hardware-Related Job Tasks





Fig. 4.4. Arrangement of Work Areas for Software-Related Job Tasks

placed on the table surface. Two participants used a wrist pad with the keyboard (participants 14 and 25).

- Two of the keyboard trays had room for the mouse to be placed on the tray. The other participant placed the mouse on the table to the side and above the keyboard tray.
- 7. Work surface height varied. The average height of the work tables where equipment was placed was between 28" and 29". The desks where equipment was placed were 29" to 31" high. Tables were 30" and 31" high.
- All participants had at least two chairs (one for themselves and one for a visitor). Two participants had three chairs because they frequently had meetings in their offices.
- 9. Three of the participants had windows next to their immediate assigned work area that caused a problem with glare on their screens during some portion of the work day. The participants stated they would adjust their window shades to control the glare when necessary.

The participants indicated a willingness to rearrange their assigned work areas to meet their specific work needs. Also, all of the participants stated the plant facilities personnel were willing to rearrange furniture or equipment when requested.

When comparing the actual workstation arrangements with suggested ergonomic standards, the workstations fell within guidelines. The only variance from suggested guidelines was in adjustability of the chairs. This was not a significant problem because the chairs were adjusted to a height that met the needs of the participant using that chair.⁹

⁹ The chairs of two participants were several inches too high for an ergonomically correct adjustment. However, they preferred their chairs at that height.

The workstation analysis indicated that participants tended to keep their workstation area arranged the way it had been arranged prior to their occupancy. The furniture and equipment had been arranged according to ergonomic specifications that provided adequate work surfaces and access to the equipment. This may suggest use of a predefined standard configuration as one way to encourage ergonomic placement of furniture and equipment. However, participants also rearranged the work area to meet their individual physical dimensions.

OSHA Assessment Form

The Occupational Safety and Health Agency (OSHA) has been developing an Ergonomic Protection Standard since 1994. OSHA had not finalized any formal statement or standard by the time of this study. An assessment form was copied from the draft document of the proposed standard and used in this study for the academic purpose of identifying potential areas of concern (see Appendix D for a copy of the OSHA Assessment Form). The form primarily guided evaluation of the workstation furnishings (chair, keyboard, mouse input device, and monitor). Posture, work pace parameters, and training were also assessed.

The items on the assessment form were rated by the researcher during the second interviews. Ratings were based on the observable conditions and information obtained from participants.

The first group of assessment questions (1-11) evaluated the participants' seated postures, adjustability of their chairs, and the placement of their keyboards and mouses. The next group of assessment questions (12-19) evaluated the participants' upper torso postures, monitor positions, and lighting of their work areas. The last group of questions (20-26) evaluated the frequency of the participants' work breaks, availability of job rotation, pacing of work, potential job enlargement, recovery time between tasks, and

training related to risk factors. The following results (refer to tables 4.6, 4.7, 4.8, shown later) indicate the presence (1) or absence (0) of items in the workstations.

OSHA Form, Questions 1 Through 11

Table 4.6 indicates the findings on seated posture, chair, and keyboard or other input devices present in the participants' workstations. Question 3 was not rated.

The following items are explanations of table 4.6:

- Adjust knee/hip angles for comfort (five of ten had areas that were adjustable for knee and hip angles).
- Footrest used (one of ten participants used a foot rest to compensate for height of chair).
- Arms/hands parallel to floor (nine of ten had chairs adjusted so arms were parallel to floor when working).
- 1d. Wrists straight and on padded surface (five of ten had padded wrist rests).
- 2a. Chair easy to adjust (two of ten had chairs that were easy to adjust with side levers; however, all chairs were adjusted to participant needs).
- 2b. Chair with padded seat pan (all had padded seat pans on chairs).
- 2c. Seat 18" wide (nine of ten had standard width chair pans; however, one chair was for a small sized participant and the chair pan was both narrower and shorter in length).
- 2d. Back rest with lumbar support (nine of ten had lumbar in back of chair).
- 2e. Stable base with casters (all had stable bases on chair with casters).
- [Question not evaluated: Does the chair manufacturer offer different seat pan lengths (15" to 17") that have a waterfall design?¹⁰].

¹⁰ This question was not evaluated because it assessed manufacturing options.

Table 4.6

		Partitipant Work Areas										
Item	Totals	11	12	13	14	15	21	22	23	24	25	
1a. knee angle	5	1	0	1	0	1	0	0	1	1	0	
1b. footrest	1	0	0	0	0	0	0	0	1	0	0	
1c. arms parallel	9	1	1	1	1	1	1	1	1	1	0	
1d. wrist straight	5	0	0	1	1	0	0	1	1	0	1	
2a. chair adjusts	2	0	0	0	1	0	0	0	1	0	0	
2b. padded seat	10	1	1	1	1	1	1	1	1	1	1	
2c. seat 18 wide	9	1	1	1	1	1	1	1	0	1	1	
2d. lumbar support	9	1	1	1	1	1	1	1	1	1	0	
2e. stable base with casters	10	1	1	1	1	1	1	1	1	1	1	
4. seat pan adjusted	2	0	0	1	1	0	0	0	0	0	0	
5. room for feet	9	1	1	1	1	0	1	1	1	1	1	
6. room for thighs	10	1	1	1	1	1	1	1	1	1	1	
7. keyboard height adjustable	4	1	0	1	1	0	0	0	1	0	0	
8. keyboard stable	4	1	0	1	1	0	0	0	1	0	0	
9. keyboard detachable	10	1	1	1	1	1	1	1	1	1	1	
10. ANSI keyboard	10	1	1	1	1	1	1	1	1	1	1	
11. input devices same level as	10	1	1	1	1	1	1	1	1	1	1	
keyboard												

OSHA Form, Questions 1 Through 11

0 = not present; 1 = present

- 4. Seat pan adjust for height and angle (two of ten had chairs that easily adjusted for height and angle; however, all chairs could be adjusted for height and angle through manipulation of knobs on bottom of chair).
- 5. Sufficient room under work area for feet/legs (nine of ten had adequate room for feet and legs).
- 6. Sufficient room between thighs and work surface (all had adequate room between top of thigh and bottom of work surface).
- 7. Keyboard height adjustable (tray) (four of ten had keyboard trays mounted under the work surface area).
- 8. Keyboard prevented from slipping when in use (four of ten had keyboards in trays that kept the keyboards from slipping; however, all

other keyboards appeared to be stable and did not slip while participants were observed working).

- Keyboard detachable (all had detachable keyboards; however, one participant also used a lap top computer that did not have a detachable keyboard).
- 10. ANSI Standard keyboard (all had standard keyboards).
- 11. Mouse, pointing device, calculator at same level as keyboard (all had mouse input devices at keyboard height either on keyboard tray or on work surface).

Questions 1a, 1b, 1d, 2a, 4, 7, and 8 were least represented in the work areas during the assessment. The most troublesome of these seven items was that the participants' wrists were usually bent with the hands reaching upward toward the keyboard. This has been found to be a cause of carpal tunnel syndrome over prolonged periods of time when the worker is continually bending the wrists and using the keyboard or mouse (Atencio 1993; Tessler 1994). One participant said he preferred to work with his wrists on the table because that was the only way he could reach the keys with large hands without overreaching the keys.

However, the lack of adjustability in the keyboard height was not an issue with the participants. From observation, four of the participants had keyboard trays that lowered the keyboards but did not allow height adjustment without disassembling the unit and moving it. It is difficult to determine if allowing easy adjustment to the keyboard height would provide any significant benefit to this group who were not suffering from any kind of wrist or arm injury.

OSHA Form, Questions 12 Through 19

Table 4.7 indicates the assessment on upper torso posture, monitor placement, and lighting present in the participants' workstations.

The following items are explanations of table 4.7:

- 12. Are the head and neck held in a neutral posture? (nine of ten had their head and neck in a neutral posture; however, one participant wore bifocal lens in his glasses that caused him to tilt his head upward.)
- 13. Are arm rests provided for intensive or long duration keying jobs? (nine of ten participants had arm rests on the chairs; however, most of them did not appear to support their arms on the rests.)
- 14. Screen free from flicker (all had monitors with no apparent flicker).
- 15. Top of screen slightly below eye level (seven of ten).
- 16. Monitor swivel (all had monitors that adjusted up, down, and sideways; however, one participant had a lap top that did not have a detached monitor).
- 17. Brightness and contrast controls (all had brightness and contrast controls).
- Distance 18" to 30" from worker (nine of ten had their monitor 18" to 30" away; however, one participant had his monitor closer than 18").
- 19. Sufficient lighting without glare (five of ten had sufficient lighting; however, three participants experienced glare from windows and two experienced insufficient lighting).

There were two items (15, 19) in this group that were found to be deficit. Item 15 indicated potential neck fatigue for three of the ten participants because of the monitor position. Two participants frequently looked upward to see the data at the top

		Participant Work Areas										
Item	Totals	11	12	13	14	15	21	22	23	24	25	
12. head and neck posture	9	1	1	1	1	0	1	1	1	1	1	
13. arm rests	9	1	1	1	1	1	1	1	1	1	0	
14. screen flicker	10	1	1	1	1	1	1	1	1	1	1	
15. top of screen below eye level	7	1	1	1	1	0	1	1	0	0	1	
16. monitor swivels	10	1	1	1	1	1	1	1	1	1	1	
17. brightness and contrast controls	10	1	1	1	1	1	1	1	1	1	1	
18. monitor 18-30" from the worker	9	1	1	1	1	1	1	0	1	1	1	
19. lighting without glare	5	0	1	0	1	1	0	1	0	0	1	

Table 4.7 OSHA Form, Questions 12 Through 19

0 = not present; 1 = present

of the monitor and one participant always bent his head downward to look at the monitor screen because of his glasses. Prolonged tilting of the head can cause the neck muscles to be in a constant state of static load, which leads to muscle fatigue. The fatigue, if not eliminated, could lead to musculoskeletal disorders (refer to Fig. 2.2, a speculative model of work-related musculoskeletal disorders).

A variety of lighting conditions existed (Item 19) and ranged from very bright outside light to no daylight with low fluorescent lighting. The participants reported this as something that they would change if possible. Although three participants had adjacent windows, none of them indicated a desire to move away from the window to reduce glare on their monitor.

OSHA Form, Questions 20 Through 26

Table 4.8 indicates the findings on the frequency of work breaks, job rotation, pacing of work, job enlargement, recovery time, and training related to risk factors.

The following items are explanations of table 4.8:

Table 4.8

		Participant Work Areas										
Item	Totals	11	12	13	14	15	21	22	23	24	25	
20. uses telephone headset	0	0	0	0	0	0	0	0	0	0	0	
21. change posture frequently	8	1	1	1	1	1	1	0	1	0	1	
22. leave workstation for 10 min/hour	5	1	0	1	0	1	0	0	0	1	1	
23a. job rotation	2	0	0	1	1	0	0	0	0	0	0	
23b. self pacing	10	1	1	1	1	1	1	1	1	1	1	
23c. job enlargement	10	1	1	1	1	1	1	1	1	1	1	
23d. adequate recovery breaks	2	0	0	1	1	0	0	0	0	0	0	
24. alternating tasks	10	1	1	1	1	1	1	1	1	1	1	
25a. trained in proper posture	3	0	0	1	1	0	0	0	0	0	1	
25b. trained in proper work methods	2	0	0	0	1	0	0	0	0	0	1	
25c. trained in adjusting workstation	3	0	0	1	1	0	0	0	0	0	1	
25d. trained in awareness of risk factors	2	0	0	1	0	0	0	0	0	0	1	
25e. trained in seeking assistance	2	0	0	1	1	0	0	0	0	0	0	
26. sets own pace	10	1	1	1	1	1	1	1	1	1	1	

OSHA Form, Questions 20 Through 26

0 = not present; 1 = present

- 20. Are headsets used when frequent telephone work is combined with hand tasks such as typing, use of a calculator, or writing? (none of the participants; no telephone headsets were used by participants although one participant indicated a headset had been ordered).
- 21. Change postures frequently (eight of ten participants changed positions or walked to other locations frequently; however, two participants tended to spend long hours without breaks or moving position).
- 22. Leave workstations for 10 minutes every hour of intensive keying (five of ten participants believed they left their workstations at least once an hour but there were no required rest breaks).

- 23a. Job rotation¹¹ (two of ten participants had jobs that required them to split their time between working on a computer and working with people).
- 23b. Self-pacing (all participants had jobs that were self-pacing).
- 23c. Job enlargement (other activities besides keying) (all participants had a wide variety of job tasks that included non-computer work).
- 23d. Adequate recovery breaks (two of ten participants had at least four hours a day away from computer work).
- 24. Alternating tasks during shift (all participants changed tasks throughout the day).

Are employees trained in:

- 25a. Proper postures? (three of ten participants were aware of proper posture and work.)
- 25b. Proper work methods? (two of ten had training in ergonomics.)
- 25c. How to make adjustments to the workstation? (three of ten people knew how to adjust their workstations to meet their ergonomic needs.)
- 25d. Awareness of risk factors for musculoskeletal disorders? (two of ten people were aware of risk factors.)
- 25e. How to seek assistance with concerns? (two of ten people knew the procedures for seeking assistance from management with concerns on risk factors.)
- 26. Set own pace (all participants set their own pace).

 $^{^{11}\ {\}rm This}\ {\rm was}\ {\rm defined}\ {\rm by}\ {\rm the}\ {\rm researcher}\ {\rm to}\ {\rm mean}\ {\rm changing}\ {\rm type}\ {\rm of}\ {\rm job}\ {\rm systematically}\ {\rm and}\ {\rm regularly}.$

This final section of the assessment form focused on work habits as indicated through posture, self-pacing, and taking rest breaks. This assessment indicated that taking a formal rest break every hour or rotating tasks was not part of Innova's professional employee culture. In order to verify this, separate observations were conducted to determine rest break activity. During three different observations spanning approximately ten hours, a total of 225 people entered the three observed break room areas. Of that total, eleven people sat down to take a break. The other 214 people came in to purchase items from vending machines or got water from the water fountains or used microwave ovens to warm items or just walked through the area. This would tend to verify that employees at Innova did not sit down in the break rooms to take breaks, but it did not reveal break habits away from those areas.

Participants reported they took time away from their computers by getting a drink of water, going to the rest room, going to another employee's area to talk about a workrelated problem, or going to meetings. Some participants indicated they would leave the area to get physical exercise during their lunch breaks. The types of activity included walking, running, or swimming (Second Interview, Question 7).

During a meeting with the safety committee at Innova, the researcher expressed concern at the observed lack of employee breaks. One person present indicated that taking a break meant taking time away from an overwhelming job load and it was not something he would be inclined to do. Other people present also indicated they did not think the work culture would support employees taking ten minutes just to sit and stare out the window.

Job rotation (23a) and adequate rest recovery breaks (23d) were not possible in these jobs because of the consistent understaffing and overassignment of work. Although the jobs had a variety of tasks, the kinds of tasks for software engineering jobs were predominately computer related and 49% of the job tasks in the hardware

engineering jobs were also related to use of computers.¹² There was no variation or rotation of shifts and all participants worked a minimum of forty-five hours a week (Second Interview, Question 7).

The group of questions related to training (25a through 25e) indicated that the majority of the participants had no training on risks associated with usage of computers, proper posture, proper work methods, how to adjust a workstation, or how to seek assistance with health concerns. The company stated they had no formal training available in these areas. (Data confirming the lack of training were also gathered from the Ergonomic Concerns Quiz; see above).

Summary of OSHA Assessment Form

The items with the most deficiencies in this assessment form were in the area of training (items 25a-25e). The lack of breaks and lack of recovery periods could be explained because of a lack of training in proper posture, work methods, and how to adjust the work area.

The other items on the assessment form that indicated deficiencies in the work areas were highly biased toward the adjustable furniture produced in recent years (e.g., chairs and keyboard trays with easily accessible adjustment levers rather than knobs beneath the item or adjustment through loosening and tightening of screws). Although the chairs the participants used were adjustable, they were not designed to be easily adjusted through accessible levers.

The keyboard trays were not used for adjustability but rather for storing the keyboard under the desk. Participants did not express a desire to have or use keyboard trays. This may also be from a lack of training in risk factors. However, there is no

 $^{^{12}\,\}mathrm{Refer}$ to the findings on types of job tasks for precise data that are found earlier in this document.
overwhelming evidence that adjustable keyboard trays prevent injury and in some instances may actually place the employees' hands and wrists in awkward positions if the tray is not accurately adjusted (Carter and Banister 1994; Pheasant 1991; Tessler 1994).

The same situation applied to use of a foot rest. Only one participant desired to use a foot rest to compensate for the adjusted height of the chair. Other employees were sufficiently tall that usage of a foot rest would have placed their knees against the bottom of the table top. Also, the participants moved in and out of their workstations multiple times a day and were not sitting for long period of times.

In summary, the OSHA workstation assessment form identified areas of lack of "easily adjustable" furniture. However, the area from this assessment form that was most lacking was training. A lack of training in the proper use and adjustment of furniture and a lack of understanding of risk factors could account for the some of the other deficiencies in the assessment.

Injury

The participants were generally unaware of risk factors related to computerrelated injury. During the second interviews, participants' understanding of injury in the workplace was further assessed by asking what type of injury was common to "their profession." These are the responses:

Injury? I don't know. I don't know anyone who has been injured by my profession. (Adam 02:4)

We have had a few guys with sore wrists. One guy has a keyboard that slides out from under the table with a pad to rest his wrists. I guess it is more comfortable on his wrists typing in that position. A few people have gotten a chair for their backs. [For backaches in general?] Yes. I don't know of anybody who uses a special chair right now except for me with my pillow in my chair. The pillow has been really nice. It used to be that the front edge of the chair would dig into my legs after a couple of hours but the pillow has eliminated that. (Brent 02:4)

You know I don't really remember an injury by anybody up here in this environment. I think it is pretty safe. (Charles 02:4)

In my particular area, electrical shock once in awhile if I'm stupid. [From electrical machinery?] Yes, putting your hand where it's not supposed to be at the wrong time. (Daryl 02:4)

Brain failure. Burned out. People get tired of doing it. Some people suffer typing problems. But I've never known anyone to actually get hurt... I don't know if too many people have had serious injuries. A few people have talked about carpel tunnel stuff. [Are you aware of any people in your group that may be having problems with carpel tunnel?] No. We had a woman who used to work here. She had problems. The secretary does, but she types a lot more. (Earl 02:4)

If you talk about me personally, I have not been injured. I have heard of wrist injuries. I know of three individuals who wear wrist protectors to protect them. Two have received carpel tunnel surgery and the third one is scheduled to go in. (Glen 02:4)

None that I know of. Nobody is suffering from anything or has broken anything. [Are there any things common to your profession?] Well there is carpel tunnel. I know when I didn't have the right conditions on my monitor with the refresh rate not being fast enough, it wore me out in a couple of hours. [Physical tiredness?] Yes, my eyes, headaches, I just couldn't work for very long. But that was fixed with a glare screen on my previous monitor and this new monitor I just received, I like it a lot. It doesn't give me headaches. (Heide 02:4)

A lot of people get carpel tunnel. Other than that I can't think of any injuries. Other than a plant falls on your head or something. But carpel tunnel happens to people a lot around here. [About how many people are you aware of in your area that have carpel tunnel?] I can think of two people right off the bat just on this side of the building, this area. There have been some people upstairs. (Irene 02:4)

I haven't had any. As far as other people I guess it is mainly problems with their hands and wrist, carpal tunnel syndrome. Maybe people get a stiff neck or back problems because of sitting. (Jeff 02:4)

The specific injury mentioned by participants was carpal tunnel syndrome.

Other physical problems associated with job injuries that were mentioned were sore

wrists, backaches, and headaches. The participants in hardware-related jobs tended to

be unaware of injury related to their profession other than electrical shock or boredom

or a secretary with problems related to typing, whereas the participants in the software-

related jobs were aware of carpal tunnel injuries in other employees in their work

groups.

Reported Time on a Computer

One possible factor associated with injury is the amount of time spent working on a computer. The participants were asked, "How much time do you spend in an average day on a computer?" (Second Interview, Question 7). The amount of time participants estimated they spent on a computer reflected a difference in usage between the hardware and the software job groups:

In an eight-hour day, maybe an hour or an hour and a half. [The rest of the time you are moving around?] Following around, moving around, testing hardware. I don't know. Maybe two hours. It depends on the day. Across the year maybe that. (Adam 02b:7)

During observation of this participant, he decided he spent closer to three or four hours daily working at a computer station. He was constantly using computers to view electronic data related to tracking, design, or debugging of his products.

Other participants also indicated they had accumulated computer-time over a

period of a day:

Well, if you are talking about one computer or another, at a workstation about half of the day. If you are talking about general use of a computer, then close to ninety percent of the day. (Brent 02b:7)

Probably an hour and a half of that two hours [at the assigned workstation]. Now that has been the last two months. Normally I would spend four hours a day in here. (Charles 02b:7)

On about average, probably about four hours a day. (Daryl 02b:7)

During this particular phase, it is higher than normal. I have the computer on all day. It is probably actively doing something for me about six hours. I'm probably actually sitting here about four of them. During the previous phase where we were doing the design flow and packaging, it was down to working a couple of hours a day [on the computer]. (Earl 02b:7)

The participants with software-related job tasks appeared to spend more time

working at a computer than the participants with the hardware-related job tasks. The

number of hours spent working at a computer in a day was generally more than half of

the workday. This would indicate longer chunks of time spent at a terminal to perform

software-related jobs.

Seven hours. (Freddie 02b:7)

Due to the position I'm in, I work long hours, as many as seventy-two hours straight to get a job done. . . I've noticed that during the hours of [8:00 am to 5:00 pm] when I'm here, maybe sixty to seventy-five percent of my time is on the computers. (Glen 02b:7)

In an eight-hour day, five [hours]. . . Prior to a month ago, I was working forty-five to fifty hours a week consistently. I am taking this as a small hiatus of just working forty hours a week mostly. [Would you say forty-five to fifty is normal and will be in the future?] It has been normal for the last one and a half years. Prior to that we had enough people, we all worked forty hours a week. . . [Who determines how long you work?] My work determines how long I work with a minimum of forty hours. (Heide 02b:7)

Maybe six out of the eight hours. (Irene 02b:7)

Out of a day, I'd say six hours. . . . [What is the average hours you work per week?] Average is forty-five hours. . . . [How often do you have crunch periods when you have to meet deadlines?] Lately all of the time. It comes and goes. But the last year there has been a lot of crunch time. I mean, there was a time in January we worked basically seventy-two hours straight for a particular project. (Jeff 02b:7)

Four of the five participants with hardware-related jobs estimated four hours a day or less on a computer with the remaining time allotted to tasks not requiring a computer. The participants with software-related jobs reported working on a computer a minimum of five hours a day. Three participants averaged six hours a day on a computer and one participant reported working an average of seven hours a day at a computer. The implications of longer working hours will also be discussed in the section on stress and deadlines.

The reported hours of computer usage by participants support the ranked frequency and location ratings of activity from the Job Task Questionnaire reported above. As indicated by those factors, participants with software-related jobs are more frequently working at computer workstations than participants with hardware-related jobs.

Causes and Cures: Illness Versus Injury

During the course of interviews in this study, the researcher began to suspect that the participants did not think of Carpal Tunnel Syndrome (CTS) as a typical kind of injury. The following responses were obtained to the probe of what to do about injury:

[What would you do if you did develop an injury?] Like carpel tunnel? I have no idea. I'd go to the doctor and do the exercises or whatever was necessary, whatever the going cure is, if there is one. I guess I'd take the normal channels and see what happened. [What would normal channels be?] I've seen other people with braces on so I guess they get those somewhere and have been analyzed for carpel tunnel by a doctor. I don't know, past that I don't know. I don't know how bad it would hurt or if I could work. (Heide 02:4)

[If you were to develop symptoms in your hands or wrist, how would you handle it?] First before I go to the doctor, I'd try to change how I sit or how I type. Maybe adjust my wrist pad a little different.

[If it worsened, then what you do?] Go to the doctor. (Jeff 02:4)

The initial response to wrist problems was to attempt to change the work area and if that failed, then go to a doctor. No employees indicated they would report this as an injury to their supervisor. During the time spent observing employee behavior in the work break areas, the researcher saw a booklet on emergency procedures affixed to the bulletin boards in each break area. The booklet covered emergency evacuation in the case of fire, earthquake, or other potential hazards and reporting procedures in the case of an accident and resultant injuries. This was the only source of procedures the researcher found in any of the company documents that gave direction on what to do in the case of an injury received from an accident. An accident is an event occurring abruptly and causing immediate injury. CTS does not happen abruptly nor does it cause immediate injury but rather CTS arises from a variety of different causes over a long period of time. Therefore, CTS would not be considered to be an accidental injury in the general intent of the word *accident*.

Reporting Injuries

During the further course of the interviews, the researcher probed the

participants about their understanding of how to report injury. The following are

responses to that probe:

[Is there a procedure in your department for reporting injuries?] I'm sure there is but I don't know what it is. (Adam 03)

[Please clarify for me what the procedure is for reporting injury.] There is one. At the time we had a manual for procedures for doing that kind of thing in it. To be honest I never read it, but I know there was a section in there about that. If someone asked a question one day, the procedure was to go look it up and see what it is. But I don't know. [Did you ever have any injuries to report?] No. We never reported any injury on the job type thing. I think we skinned a knuckle and minor things but nothing that couldn't have been fixed with a bandage which we kept around. (Earl 02:4)

[If you were to injure yourself, do you know the procedure in your department for reporting injury?] I don't. There is a first aid station down on the second floor. I'm not sure but you would probably call security or your supervisor. That is what I would probably do. It has probably been told to me. We all have an employee handbook and there is a section in there on emergencies and things like that. I'm sure it is outlined and I have forgotten. Or maybe I have never read it. Injuries aren't real common here. Although there could be an emergency like a fire. We do have fire drills in fact it [the fire alarm] is right here. When it goes off, it throws me right out of my seat. (Jeff 02:4)

The most informative comment related to attitudes toward injury came from one

participant who was questioned in depth about how to report and handle computer-

related injury if he determined there was a problem:

[One of the things I'm not too sure about. I have asked several people if they developed carpel tunnel, what would they do. The consistent reply is "I would go to the doctor" which is logical. However, I don't have the feeling anyone would report this as an injury related to computers. [Is that an accurate estimate of people's understanding of carpal tunnel?] Yes, I guess. Depending on which medical plan they have, there are like three of them, I think most of the insurance would pay for it no matter how you got it. There would be no reason to report it. It would be like if you had gall stones, you go to the doctor and he would say here is what we will do. If you had carpal tunnel problems then you would go to the doctor and they would say, here is what we are going to do.

I do know one of the people who worked here had what they thought was carpal tunnel problems. And some of the things the company will do without a doctor's prescriptions is wrist pads, change the height of the table if that will help you, they will change the chair. In fact they will provide a different selection of chairs. They have a standard with the red back on it. They have secretary chairs that are better for working. They were actually designed for sitting and working with your arms up. So they have a bigger version of that they will provide. If you wanted to, they would actually buy you really homely wrist braces. Those things are listed in the company's office products catalog and they would purchase you one. So I guess there is low incentive to report it as a separate injury, it is treated as an illness I think. (Earl 03:1)

Although the OSHA 200 Log¹³ of the company did show reports of problems

with wrists or hands and carpal tunnel syndrome, it was unclear if the people reporting the injury first sough to change their work environment or asked advice from their physician or reported it as an injury to their supervisor. The above participant's response indicated that a carpal tunnel syndrome injury was a type of problem that employees would not report as an injury to their supervisor but rather as a health problem to their doctor.

From other participant responses listed above, the apparent underlying trend would be for employees to first seek to correct the problem through supplemental devices such as wrist braces, pads to support their wrists, or changes in their workstation furniture height adjustments. The participants all indicated they had experience and faith that the company would provide assistance in the form of assistive devices or by changing the work environment at the employee's request to reduce injury or eliminate the pain causing condition. If changing the environment or adding assistive devices failed, then employees would seek medical assistance and rely on

¹³ This is the means by which businesses report injury to OSHA. The log specifies types of injury, type of occupations, and days away from work.

private medical care rather than report the problem because there was no perceivable gain for reporting it to the company.

The nature of the jobs in this workplace did not allow for transfer to another type of professional job within the company because all of the professional positions were heavily dependent on computers for job task performance. One participant explained why he believed he would lose his job if he became injured:

[One of the problems with carpal tunnel is it reduces a person's ability to work on a computer, and thereby, reduces the person's ability to do what you guys do. How is that handled as far as the work load?] It would be very difficult to make any reasonable allowances long-term if you couldn't [work at a computer]. If you had a job as a carpenter and you couldn't use the saw or swing the hammer, what can you do? So I'm not aware of a way they could, you know it isn't that we could say, "Well we could find a way where you won't have to do that." They are certainly willing to go to some lengths to see if they can alleviate it. They will say is it your workstation, if we buy you a funky chair and have you lean forward, it will that help. We can raise and lower the table. I don't believe there is anyway they can say, "Well we won't have you not type." Short term they could do that. You would probably be just as well off to take short-term disability and go home and put your feet up. But I'm not aware of any way they could fix that problem on a long-term basis except for rearranging the work area so it doesn't bother you....We've had people with spacey split keyboard things and people are continually messing with that. Within those limits, I mean if I needed a new keyboard if I said, hey, my hands are killing me, I need a new keyboard. They would probably go, "OK, we can do that." If I said I need my keyboard closer to the floor, they would come in and change it. But if I said, I can't run this, they'd say, well gees, you should think about going to school and getting in a different line of work. (Earl 03:1)

The employees at Innova may have believed there were no alternatives to getting

their job done through assistance from another person or other alternative ways of

accessing and using the computer. A combination of these elements may also have

caused a lower level of injury reports to the company.

Summary and Discussion of Workstations

The ultimate reasons for creating workstations are to promote safety and job

task efficiency. There was an expressed concern on the part of both the safety

committee and the plant facilities manager to provide a healthful, safe work

environment through ergonomic solutions. The participants in this study were intensive computer users with continuous contact with computer equipment and computer furniture, and yet they reported no chronic pain or health problems.

According to the sources at Innova, the first line of defense in the company for reduction of injury to employees was correction of possible problems in the physical layout of employee workstation areas. The company arranged the work areas based on plans designed by a company specializing in adjustable, ergonomically correct furniture. However, employees rearranged the areas according to the personal needs.

The initial arrangement of the work area was done by both the physical plant personnel who set up the furniture and the network manager who set up the equipment. There was an underlying assumption by employees that these two sources of assistance would know how to correctly arrange the heights and distances of the keyboard and monitor for the workers. However, through a question asked of the physical plant manager at Innova, it was determined by the researcher that the network personnel depended on the physical plant facilities personnel to understand and implement ergonomic standards. At Innova, the only source of ergonomic expertise was select physical plant personnel who checked and adjusted work areas but only upon request.

Although Innova utilized plans for ergonomic placement of furniture, the OSHA assessment form identified furniture that was lacking easy adjustability. The underlying actuality for computer furniture at Innova was that a majority of the chairs and keyboard trays had adjustability but without easy access to levers. The assessment also identified a lack of training in identification of risk factors that may led to injury.

The participants reported that the physical plant personnel were willing to work with them in order to reduce problems with pain or discomfort. Whenever requested, the physical plant personnel would assist the employee in rearranging work areas or adding assistive devices, such as keyboard trays or wrist pads.

Participants were aware of their unique physical dimensions and the need to adjust their hardware or furniture accordingly. However, the participants were not acting with any focused purpose in altering their work area other than changing placement of items if they were already experiencing pain. Physical plant personnel would only respond to a formal request to rearrange the workstations from an employee who was already experiencing pain.

Injury in this workplace (i.e., carpal tunnel syndrome, sore wrists, backaches, and headaches) was not perceived to be injury in the sense of a sudden accident, but rather was viewed as weaknesses or as a problem that could be corrected by changing furniture heights or placement or by going to a doctor. The first strategy to alleviate a physical problem causing discomfort was rearranging furniture or adding assistive devices. If that strategy failed, then employees stated they would seek medical assistance and rely on private medical care rather than report the injury because there was no perceivable gain for reporting it as an injury to the company. The computer intensive nature of the types of jobs in this workplace did not allow for transfer to another type of professional job within the company that did not require computer usage. A combination of these elements may have caused a lower level of reported injury to the company and a higher incidence of managed illness through medical plans.

The participants also had little or no ergonomic training in setting up a work area nor did they have a technical knowledge of the items related to the ergonomic positioning of people and/or furniture. The findings from the second interview generally indicated participants had an experienced-based knowledge of ergonomic issues and used that experience to rearrange their work areas.

Stress

The previous sections have provided the finding on elements within the job task model. This final section of findings presents findings on the fourth factor in this study: stress factors that may contribute toward injury. There is growing evidence that musculoskeletal disorders may not be caused by purely biomechanical factors such as seated work, awkward positions, static work, inactivity, overuse injury, stress on bone and connective tissue, or pressure on blood vessels and nerves because of a lack of circulation (Bergqvist et al. 1995; Carter and Banister 1994; Hales et al. 1994; Pheasant 1991). These sources identified several psychosocial factors arising within workplace settings that were associated with computer-related injury (refer to table 2.3, a summary of factors influencing computer-related injury).

The participants reported that stress in the workplace primarily arose from completing tasks and meeting deadlines. The first factor to be explored in these findings is how tasks were assigned.

An understanding of the definitions for stress factors emerges from participants' descriptions of what they believed stress was and how stress affected them and their fellow employees. Participants also provided explanations of how they dealt with stress and what things they believed the company did to reduce stress in the workplace. The primary guiding question for this section of the study was "What are the stress factors in this workplace setting?"

Task Assignment

During the third interviews, the participants were initially asked how tasks were assigned in their work group and who assigned the tasks? The participants were also asked to describe how they knew when a task was completed. Innova used several processes for assigning tasks. However, there was an interesting difference between

when the hardware engineers believed they had completed tasks and when the software engineers believed they had completed tasks.

Assigning Tasks

The variety of tasks revolved around the phase of design or production within a

larger project. Sometimes the tasks were systematically assigned by managers:

It depends on what is going on. There is on-going work to maintaining existing products. Whenever a request for a change comes in, that's called a SCR—system change request—then those are partitioned out and given to the different engineers to handle. Those are given to your supervisor as a result of someone complaining. The product manager of that product may accept or reject that complaint. If he accepts it then the supervisor over that function assigns one of his engineers to solve it. There is also ongoing new development in which case, the manager becomes aware there are changes or improvements that need to be made and assigns that to somebody. (Adam 03:2)

We get system change requests on line. We get an e-mail message telling us we have it, so we can pull it up. It tells us about the problem and who to talk to about it in detail or shows us the problem in the system. (Brent 03:2)

Usually my supervisor tells me I have a project that needs to be done. The supervisor is historically both a decision maker and a conduit of political information as a former manager referred to it. They know at a higher level the individual they are looking for, either by name or qualification. If not, they say we have a task that has to be done and assigns someone. A lot lately, they have been saying we don't have the manpower to support what you want, so what program do you not want to have finished. . . . The supervisor has to globally see all of the manpower issues and approve them. The manager works with the supervisor to make decisions about who works on projects. The two people responsible for my time get asked for my resources by program managers and project engineers. (Glen 03:2)

Previous to this implementation we have started, the tasks came from the users and I addressed whatever needed to be done at the moment. Then came a moratorium on any kind of enhancements or upgrades to the old system. Then the [software] implementation started. Technically we are getting our assignment through one person that tells us what our projects are for the week, ranked in order of importance. (Heide 03:2)

Mainly a supervisor, my immediate supervisor, and sometimes the manager above him. It goes about that high. Sometimes program managers are involved who are kind of removed from us. They have somewhat of a say in who should be involved. (Jeff 03:2)

Some tasks were assigned according to availability of employees:

On the fly. There is an attempt to put together a tactical plan to say that different people will be responsible for different things. And that is good. It sums up areas of ownership. But when unforeseen tasks come up, they just get assigned on the fly to whoever has time on their hands or expertise fitting that task. (Charles 03:2)

I know on this current [task], one day having no input from me or as near as I can tell from anybody else, my name as signed up associated with part of the project. Clearly someone did that. I don't know if somebody did that using a dart board or they sat around and thought about it.... [Your supervisor oversees the big tasks?] Yes. He says what do we have to do, here is what we are going to do. If you express an interest, they will either note that or not, and frequently they will come up and say, "We know you wanted to do that but you aren't available, and we can't shuffle things around. Maybe next time." (Earl 03:2)

Some of the tasks were divided amongst themselves by the employees:

When it comes down to whether we are going to put a certain feature in the software or not, then the managers decide. But right now the system we wanted to do the interim delivery on, a group of people sat down and decided what we need to do to get the interim deliver ready, and then gave the task list to myself and the other guy working on it. We split it up between ourselves and let our manager know who was handling what tasks. We think we can get it done in this amount of time. (Freddie 03:2)

Some of the tasks were assigned because the employee had prior knowledge of the

project:

A couple of different ways. Sometimes it is just the person who gets freed up, gets the next thing that is most urgent. Sometimes only certain people are better fitted to certain tasks. Those tasks come up so it is just a better fit for one person over another. It gets given to that person. Sometimes it is availability, sometimes it is the best fit. It depends on your boss. Sometimes they try and listen to their employees about the kinds of tasks you would like to do and try to give it to the person who would most like to do it. It happens, but not all of the time. . . . When it comes to software too, sometimes if a piece of software needs to be worked on and it really doesn't have an owner. Then when that software gets assigned to any one particular person whenever work comes along on that particular piece of software, that person gets that task. Not always, but most of the time. If there is a lot of work on a piece of software and your name is associated with that software, you get a lot of work.

[So you are careful what you volunteer for.] Yes. (Irene 03:2)

The supervisor was the primary source for task assignment. The participants

were assigned to provide a solution to a problem because of his or her job title,

associated skills, or simply because of availability of that participant. Also in some

instances, participants would meet with other members of the project team, and through a volunteer process, decide who would take responsibility for various types of tasks.

The participants could request certain task assignments within the project team. One participant explained the team process:

[Why do you think there is a lot of cooperative activity here for working together?] Because for the most part no one is in the position to do everything. Usually there are from three to seven people working together for the course of four months¹⁴ to two years. You are constantly interacting with people and realize that my part from the production stand point is only one part of the whole that is going to be delivered. That is in my department. But you extend that into the production area and you realize we are a part of a team by default. No one is going to be able to accomplish the project without assistance. So from that standpoint, ninety percent of the time, no one person can build the [software] alone. (Glen 03:2)

The length of tasks within projects was variable. Multiple types of tasks were

completed by different work groups to complete parts of the larger project process.

This created a team process because of the size and complexity of the projects.

Completion of Tasks

After the participants discussed how tasks were assigned, they were asked,

"How do you know when you have satisfactorily completed an assigned task?" The

participants with hardware-related job tasks had a tangible method of determining when

a project was completed:

That is pretty easy. Everybody is happy. The tasks in this area are very easy to define when they are over. They work. (Earl 03:2)

There were also more formal ways to indicate completion of tasks:

Some of them are well defined. The SCR tracks most of the work we do here. There is always a description of what needs to get done....So you first look at it and move it through states of progression. You start out and you are analyzing and developing and implementing and testing and verifying. Each

¹⁴ Some tasks were based on quarterly performance goals and would be tied to an end of the quarter cycle.

one of those people moves it from category to category until it is closed. You know you are done and wash your hands of it. (Adam 03:2)

One way is that our assigned tasks are monitored. A lot of them are on-line assignments in Issues. We have to actually close out that when we accomplish the task and complete the job and define what we did, the corrective action, and that is trackable. On-going projects are a little harder because you have milestones you have to be meet and they are not tracked quite as well. But we still have to report on those. (Daryl 03:2)

However, even the most precise approaches could not always anticipate problems:

If a task is not tied to the SCR system then you're right, it is a little more nebulous. If it is a single thing that is larger than you can write into a single task, then we write a specification or design document and work to the document although typically the document would break down into a bunch of SCRs. That is the direction the company would like to go. Even on new development they would like to write SCRs saying here are the tasks because it is an easy way to track things. I find it a little annoying because there is all that moving from category to category. At least at the end of the day everyone knows what has been done and who's working on what. (Adam 03:2)

Software engineers approached task completion differently from hardware

engineers. A task was determined to be completed when the software engineer thought

it was done.

Oh, basically we get together and talk about how we are going to approach it. If it is really complex, we write a design document. Normally we just kind of discuss it. If it is anything that requires any kind of how-do-we-do-this, one of us just goes off and does it and tests it very thoroughly to make sure there are no problems with the rest of the software and then implements it back with everyone else's code. We do have some tests that we run on some of the software. I'm usually the one that does that. If everything seems to look pretty good, then off it goes. (Freddie 03:2)

Sometimes it is real fuzzy. Most of the time when I am given a task if I don't understand everything it entails, that is the first thing I try to find out. Now what am I doing here. I try and find out all of the details. Then from there I do the work until I feel like I've done everything. I think it is usually up to the individual to decide if they think it's finished. . . . A lot of tasks aren't really, really clearly defined. We have to do this, this, and this. Most things are not really spelled out that well. It is up to the individual to do a good job and complete the task. . . . [On those tasks that are fuzzy, what is your personal criteria for when you say that's it, I'm done?] I'm probably a little bit to the extreme. I'm really nervous about it until, so I really—maybe it is my own personal way, but I maybe spend too much time. I test it this way, test it that way, try it that way even though it might not ever get used that way. I hate to be in the position down the line that some user goes to use my software and they

find it is flaky or buggy or something. So I try as best I can to avoid that. (Irene 03:2)

Completion of a software project was also based on when the customer

approved of the look and feel of a piece of software:

Usually there is some sort of a review that needed the work. It can be an inhouse person or an actual customer database review. They sit down with us and look at the IG [image generator] and say "I like this. I like this. I don't like this, how can you fix it? Will that be acceptable?" "Yes, that will be acceptable." Then we fix it, we show them the fix, then they sign off on it. For an inside review, it is less formal, but whoever is paying for my time has to be satisfied with the look of the database. (Glen 03:2)

You ought to know in writing software, it is always going to have bugs. You wished you could write a program that would never have bugs or exactly what the customer wants. What they might consider a bug, you might consider not to be a feature of the program. They may say, "I've done a conversion and I was supposed to get textures." And you can come back and say "Wait a minute that wasn't a feature of the program." But there are definite bugs where the program hangs or doesn't work right in certain instances. Between the customer and you, the software product is never done. The longer it has been out, the better you feel about it. If you have written a program the customer has used for a couple of years, the more use it gets, the more bugs are found and fixed. When a program is written and seldom used, that is what scares me. Because all of a sudden a customer will have to use it for something really important, and they are using it in a way you weren't expecting, and it doesn't work. (Jeff 03:2)

dissimilarities between the two categories of jobs. Both hardware and software engineers recognized the ultimate criterion: it works. However, the hardware group indicated a more structured, traceable process for completion of tasks than the software group, who indicated they used their own opinion or were guided by someonelse's opinion for deciding when the product worked.

In the area of tracking task completion, there were both similarities and

It may be argued that both types of jobs worked with a defined design document. However, in software engineering there was the underlying, mutable nature of software that caused it to do something it was not designed to do or not do something the customer thought it ought to do. In both instances, the software code might have performed exactly to the design specifications but failed the ultimate test of meeting user needs. The unforeseen needs of a customer might also have been a problem in production of hardware; however, the participant responses indicated a psychologically clearer line of completion for hardware through the service change request (SCR) project tracking process. They knew a project was done because everyone had signed off and it worked.

During the data analysis, the researcher noticed no mention of the SCR tracking system by the participants with software-related jobs. This resulted in contact with a participant in a software-related job to determine if the software groups also used the SCR tracking system. The researcher was told the SCR system was a part of the software production process and was implemented in the same manner.

It is uncertain if the underlying process of letting go of a product was related to the type of product or differences within the departments for testing and final delivery of products. However, the hardware engineer assumption that a task was done when "it works" had a different bias than the software engineer assumption that "it works when I think it does." This may indicate a subtle psychosocial factor requiring further research and clarification beyond the scope of this current study.

Project Deadlines

The participants were asked how project deadlines were determined and who determined deadlines. The types of deadlines reported below were both internal and external deadlines.

Typical Deadlines

The internal deadlines were driven by products being developed for use by the company (i.e., proprietary software or products still in the research and design stage). External deadlines were set to meet delivery dates for contract orders to customers or for presenting new products at trade shows. Within the external deadlines, there were

also internal deadlines for production of hardware parts that had to be produced before the software could be tested. A final integration of both hardware and software needed to occur before delivery of a completed image generation system.

Setting Deadlines

The process of determining project deadlines was a negotiated process driven by customer needs and availability of employees or parts.

Let's see, the program managers are the ones who need deadlines obviously. They are the ones who ultimately need to satisfy a customer by a given date. They go to engineering and say we need such and such and engineering says we can give it to you by this date. The program manager says "Great," and tells his customer. Sometimes it happens that way. Most of the time it doesn't happen that way. They negotiate with the customer and end up with a drop dead date¹⁵ and go back to engineering and say it has to happen by here. Engineering says OK, I guess even though we have said no it will take no longer than that. (Adam 03:3)

[We have talked about the project deadlines being driven by contract and customer need, right?] Right. Customer need. After a proposal has been accepted, and everyone involved has talked to the customers, then they come to us and try to break it down into tasks and determine how long it will take. That is when we come back to the customer and say this is when we can have it...then the customer says, no way, we need it right now. Then we compromise with them and get an interim system to start playing with it and integrate into their system. (Freddie 03:3)

Mainly by the supervisor and product manager and customer needs. The supervisors and product managers look at resources and sometimes there aren't enough resources to put on the problem so the project slips for that reason. There is some negotiation between us and the product managers. We will say we just can't do it in that amount of time and there is some push back from them telling us to find a way to do it in that amount of time.... [Do you have any kind of input about the deadline?] Some. They will ask me how long I think it will take to do this kind of a thing. They ask for me to give them an estimate. [Do they hold you to it?] Yes, you bet. Unless they look at it and disagree with it and change it one way or another. (Brent 03:3)

There were also daily deadlines within the larger project deadlines:

¹⁵ A drop dead date is a term used to indicate the last possible date a project can be completed before the project is no longer a viable project or serious financial repercussions will occur because the project is late.

On the big projects, management sets them. On the day to day operations, like when I was doing the day to day fire stomping of fixing things that were broken, my priority was I fixed whatever was hindering business the most. [You have little deadlines, like daily leaks to fix, and you have the bigger deadlines set by management?] Right, and there is very little in between there. My own personal deadline is to get it done just as fast as I can because I know how frustrating it is not to be able to do your job. I put myself in the users place where they are sitting there saying, "Gees, I can't get anything done." I know I don't like being in that position and so I want to get them out of that position. (Heide 03:3)

Determining the overall product deadline required parallel development of both

hardware and software:

There are two aspects: customer driven and noncustomer driven. When it is customer driven, there is a specification that says by this date the work will be done. A subset of that date, there will be interaction between the database lead, his supervisor, and the program and project engineers. They will determine at what point the database needs to be done so they can build what is called the final acceptance test procedures. That way, we develop the software at the same time the hardware is being produced. It could be a new system or an existing system that needs to have the cards built. The software development proceeds in parallel. At some point they will need a finished database that has been formally accepted by the customer to go along with the hardware. Once the two have been married up, the customer will come in and accept the hardware, accept the software. Once the signature is on those last documents, we have fulfilled our contract. It is all contract driven. (Glen 03:3)

Determining deadlines was not always precise. Often, it involved a best guess

that could not identify potential problems that would delay completion:

Nobody in project planning seems to have an inkling about what it takes to do it. So they come up with some sort of magic guess about how long it will take to do that and they are usually off by several orders of magnitude. For example, two years ago the project I'm currently working on, was assumed we would send it to the guy who would fab it in June, not the last year but the year before that. They then slipped it out to September. They then slipped it out to June. I told them OK, I'll go on vacation in July because this thing will be done. The truth was it wasn't even started. I came back last July and they said the [fabrication] is next March. I said OK. Currently it is looking like it should be done in October but I personally wouldn't put any money on it. We are getting closer. We are actually working on it now, which is something we weren't doing last year at this time. . . . [What should drive deadlines?] Somebody's reasonable guess about how long it's going to take to do it. . . . That is very much the way this work. You sell something and that determines the schedule and in truth, it really does. A couple of times we have gotten into serious trouble because the contract said we were going to deliver it and we weren't even close. Some companies who have been burned by that sort of

thing write penalties into their contracts which we eat a huge amount of sometimes. (Earl 03:3)

There were three types of deadlines: (1) customer driven (external deadline), (2) management and product driven (internal deadline), and (3) employee driven (daily deadlines). Setting a deadline was guided by the interaction between customer needs and the availability of people in the various departments to perform the development tasks. Setting the deadline was a negotiated process between customers, project managers, and department managers. The employees had little control of the deadline date.

Customer-driven deadlines were more flexible than deadlines determined by trade shows. The internal deadline for trade shows required Innova personnel to have product ready to show in order to attract new business. The deadlines for trade shows could not be renegotiated.

They have to have a product developed and designed to go to a trade show to meet a fixed deadline. Otherwise there is a large impact. We lose a large potential for sales because we didn't meet a deadline. [But with] ours, we have to meet a customers' requirement. Even then it is easier to juggle this and juggle that to slip the schedule here and impact it here and still meet the deadline or to slip the deadline than these deadlines that you can't slip like a trade show. Yet I don't know how much of their design work is impacted by that trade show deadline. There are just a few I know of though.

Yes, but there is a survey out that says if you miss your window of opportunity why you—everything is changing so fast that they really rely on those [trade shows].

Technology gets introduced to the marketplace faster than it ever has and can go by you. (Charles and Daryl 03:4)

In the case of trade show deadlines, there was pressure to deliver completed products coupled with the inability to control the deadline. Not meeting a trade show deadline could mean loss of future revenue and perhaps jobs. If a product deadline was not met, then there were severe consequences in the form of penalties or lawsuits against the company. These situations caused stress in the workplace. In summary, tasks were primarily assigned by management to meet customer needs. There were three kinds of deadlines: external, internal, and personal. Deadlines were also determined by management and customers. The employees had little or no control over task assignments and deadline dates.

Stress Defined

After the participants described how their tasks and deadlines were assigned and completed, the participants were asked to define stress and list associated physical or mental symptoms. Undoubtedly the order of the questioning introduced bias in the participants' definitions of stress that lead to exclusion of factors outside the workplace; however, this approach focused the participant responses on stress factors inside the workplace.

The following explanations were given about what the participants believed caused them to experience stress. Some people attributed stress buildup to the flow of work:

Well anxiety about what stuff is actually going to get done. The most stressful thing to me is, these programs we work on are so vast and so many things going on, that I always get this impression in the back of my mind that there are twenty things that we haven't even thought of yet that also needs to get done. That is where I started to feel stressed. I'm sitting in a meeting and I'm telling a program manager we are going to be done on a certain day and there are probably twenty things I haven't even thought of. He isn't going to know I haven't thought of them. If new things come up, he expects me to just deal with them and be done on time. That's the only time I really feel stress, when there are things undefined or I haven't thought of, that get thrown into the mix. It always happens. (Adam 03:4)

Most probably frustration. It is when I become frustrated at either not being able to figure out a problem and especially at needing to have something done within a certain time frame and having a difficult time doing that. It is when I become frustrated with the situation that I can no longer be happy and relaxed about it. (Freddie 03:4)

For me stress is when I feel more than a comfortable amount of pressure to accomplish a task, whether the task be large in scope or short in time frame. The double whammy is when it is both large in scope and short in time frame. You have stress from two different levels. It is also, in my case, an expectation that I have pulled off the impossible before and sometimes the impossible is easy and sometimes it isn't so easy. There is an expectation that I can do about anything if I am given enough time. (Glen 03:4)

One person defined stress as a product of the environment:

[The other day in the test area, you mentioned that the noise had an effect on you.] Yes there is an effect. Some people really get exhausted from that kind of noise. Random noise isn't quite as bad for me though. Things going on that have some kind of intelligence has always distracted me. I do better with random noise than I do with specific conversations or something like that going on. (Brent 03:6)

Some participants said stress was created by interacting with other people:

But you know a lot of the stress in our workplace comes from interfacing with different levels of people. We are engineers and we interface with production workers and we have these quirky ideas about how something should be done and we get frustrated with them because they don't do it the way we want it to be done because we are sure it will work better. So we go back and forth and we have these frustration levels because we say you didn't work the way we told you to and they say, hey, we've been doing this for seven years and it has always worked. So we say yes, it works for this application but not for everything. And it doesn't satisfy this customer even though it satisfies that customer. So that is what I think more of, the not stress, but frustration comes from. Just the relationship of dealing with people's personality, attitudes, work ethics. (Charles 03:4)

There is all of this external force that comes upon you and stress is how you deal with it. The force isn't going to go away. It is people trying to do everything at once or people who don't know how to plan very well. Stress is really hard to define because it can come on you in so many different ways. (Jeff 03:4)

One person said stress was created by the expectations of management:

If the whole company's future is resting on you and you are botching it up, you feel some stress. Nerves go to hell and you can't sleep. Any group of classical symptoms you'd like from physical ones to hair falling out or whatever....The most stress is being in hopeless situations. Like the schedule is one. If the schedule had sort of a glimmer of reality, you might have some feeling that you could meet it. But faced with impossibilities there's nothing you can do that will possibly make this work.

You really, everybody I know, wants to build the product right. Everyone understands you can't take forever. There has to be somewhere you say I'm ninety-eight percent sure this is working, build it. There has certainly to be a cut-off....Things that you can do, that you are comfortable with, is not too stressful. So building the product is not where the stress is. (Earl 03:4)

Some participants defined stress as self-imposed:

Self imposed, sometimes. Not feeling like you can accomplish all you want to accomplish, or that you think someone else wants you to accomplish. It is an expectation thing. I think a lot of [stress] comes from knowing that if you don't do this in the right order or format, it will impact something coming down the road and then it will be an issue. Why didn't this get done in time? Now this system has to wait. So you lay awake at night thinking oh I should have done this today because if this thing shows up tomorrow, I'm late. So there is always some unknown factor in there. You just have to figure out some way to stay ahead of the ball. That's not bad. Usually you can see the forecast. . . . Our stress probably comes from—we know we can do something but we may not have the technology or machines to do that yet. So it takes us a little while to learn that and integrate it and bring it in. So we have some deadlines to meet their deadlines. (Charles 03:4)

I think that is when I feel the most stress [when stress is self-imposed], that I know I can't do things yet I'm expected to do them. So I have to lay them down one at a time. And say OK now I can do this, then I can do this, then I can do this. This alleviates some of the stress because you know you are attacking it systematically. But still you know you have all of this to do in the back of your mind and it builds up and builds up. . . . I honestly don't think the management imposes much stress on us. They assume we are professionals and we know what job we have to do and they let us do it in our own way. If you have any initiative at all, you will, instead, let it go. (Daryl 03:4)

The other part of stress for me is lack of self-confidence where you sit and say, "I don't know if I'll ever learn this. People will find out I don't know anything. I'm not up to this." You know. It is all self-imposed. Those are the two parts of stress for me. [The other part of stress was dealing with deadlines.] (Heide 03:4)

The causes of stress at Innova were both internally produced and externally

produced. The internally produced stress factors were created through self-

expectations, lack of control of a situation, interacting with people, being concerned

that something important had been forgotten and would cause delays in production, or

not knowing how to do a specific task. One participant described a cause of his internal

state of stress as arising from "the illusion of necessity."

There was an interview with a football type on TV once and the guy was saying that what he really liked was the illusion of being required, the illusion of necessity, they really needed him. Everyone likes that you see. So when they come up and ask you if you can do something and then you immediately feel good and say, "Oh, yes, yes, I can do that." Because you have now believed that you are required or necessary, you tend to promise that you can do things that you should really be saying no for. I think it is this illusion of necessity that causes people to do that sort of thing. (Earl 03:7) Externally produced stress arose from deadlines, noise in the environment, or trying to accomplishing tasks in short time frames. Whether the stress was coming from external or internal sources, the common factor seemed to have been a lack of control over events. The participants reported symptoms of stress ranging from none to nausea (see table 4.9).

These stress definitions resemble the types of psychosocial factors found in previous studies cited in this study (Aronsson, Dallner, and Åborg 1994; Bergqvist et al. 1995; Christie and Gardiner 1990; Hales et al. 1994; National Institute for Occupational Safety and Health 1993; Sauter and Swanson 1996). See table 2.3 for a listing of the biological or individual factors identified in previous studies that correlated with computer-related injury.

Other People's Stress

Summary of Reported Symptoms of Stress

In order to gather extended information on general stress at Innova, the

Participant	Physical Symptoms	Mental Symptoms
Adam	None	Worry outside of work
Brent	Muscle tiredness, fatigue from noise	Mind wandering
Charles	Yawning, headaches	None
Daryl	Hunger, sleeplessness	Irritable
Earl	Canker sores, pain in neck	Self-doubt
Freddie	Tight muscles, grinding teeth	Fuzzy thought
Glen	Problems with sleeping	Anxiety
Heide	Tightness in shoulders and back	Short temper
Irene	Increased heart rate, sensation in stomach	Panic, worry, dreams
Jeff	Nausea, diarrhea	Worry

Table 4.9

participants were asked to report on the kinds of situations that may cause stress in fellow workers. The participants were asked, "If one of your fellow workers gets really upset at something at work, what usually is the cause of the problem?" (Third Interview, Question 5). A common response was that interacting with other people caused stress:

People... It's people and people's feeling and people's turf and territory and that kind of stuff. It is almost always what it is when people get upset. (Adam 03:5)

People. I think in general, engineers are not necessarily the most social group in the world. . . . A lot of engineers are not really social. By necessity we are thrown together in social context. I mean you have to work with each other. Therefore a certain amount of conflict arises. Engineers work pretty well with the inanimate objects around them. Computers and the like, I think they get along pretty well. You see people frustrated at working with software tools and stuff. But the most anger and conflict I've seen is directed at other idiot individuals. (Earl 03:5)

Some stress was caused by a lack of resources:

Sometimes systems don't work together very well. Systems in the company or perhaps policies. Some of it might be a lack of tools like a software manual or only one license for the piece of software and so the whole company has to share it. This causes the most frustration. [Not having enough software that you need?] Yes, or not having the software that is sufficient for our needs. (Brent 03:5)

Too much. Too much to do. I have seen it mainly on [person in group]. He just has too much on his shoulders. He still gets pulled in on all other those projects that the same things are going on with the customers. They got it months ago, they are testing it now, they are finding problems, they are threatening to sue. He said, "We've got a crisis. We've got a crisis." He is just being pulled so many ways. I think it's frustrating to him because we tried to deliver the stuff a long time ago and we sit with acceptance test plans and go through the tests with the customer and it's like, yeah, thank you, get out of our face. Then months later they'll test it and come back screaming at your door. He's in charge of so many things and everyone is asking him about everything. It is just too much. (Freddie 03:5)

Some stress was caused by either a lack of communication or too much of it:

Probably one of the bigger ones is where someone has misunderstood either the instruction, the assignment, or what was supposed to happen. It was misunderstood or miscommunicated from the source. It ends up making somebody look bad. Obviously that can cause some real animosity between people. (Heide 03:5)

Problems with programs. I've seen people get upset when too many problems or things happen at one time. I'll go over and ask a fellow worker if they can fix a bug and someone else had been in their office two minutes before with their problem so they are fixing that problem. So there are things piling up and that causes irritation in people. (Jeff 03:5)

The participants believed the interaction with people and the lack of time were the primary sources of stress in other employees. These responses also matched the participants' description of the factors that caused stress in themselves. The external factors included things that could not be controlled (e.g., deadlines that were set by other people), having too much to do in too short a time frame, and miscommunication with other people about the content of work.

Reduction of the Effects of Stress

After participants reported the types and causes of stress, they were asked how to reduce the causes of stress for themselves and how the company reduced the causes of stress for employees. These were the stress reduction methods that involved physical activity:

If you can, listen to music. Getting up and walking around once every couple of hours is good. One thing that has helped me a lot is the process of focusing. (Brent 03:7)

Well probably I'd actually tell them the easiest one is to do the workout thing. It really is a good stress reliever. I have found it really useful for the last year to mellow out. I think the secret may be to do something that takes your mind off of it. I think the real secret, as I said earlier is the things that give you the stress is the things you can't do anything about. If you can't do anything about it, why are you stressed out about it? Is there anything you can do? If maybe there was, you could move it into the category of OK maybe I can help. But if it is just external pressure being applied, hey, you aren't going to give me ulcers. If you want to worry about it, do it. (Earl 03:7)

Some participants believed stress reduction came from within themselves:

If there is some factor that is making you extremely uncomfortable, how can I put this, if it is something you have control over and you feel it can be fixed, then you need to talk to somebody about it... You need to moderate for

yourself. Number one is the one you look out for anyway. So you need to take care of what you can take care of that you feel is reasonable. Alleviating that other stress about not feeling adequate is that power of positive thinking. You have to think about what you do know and what you have accomplished. It is that good talking to yourself that relieves that kind of stress for the moment.... I have [a saying] on my board that says "Don't be surprised to find that luck favors those who are prepared." I live by that one. The other one is "If you don't ask, you don't get." If you ask, the worse they can say is no. I've gotten so many things because I asked. If it isn't reasonable, you shouldn't ask. (Heide 03:7)

Sometimes it is just plain hard to avoid it. Really I don't think there is much you can do as far as external things, whether they be deadlines where the customer calls in and says we found a bug in your software, fix it. Those kinds of things, you just have to deal with it within yourself and try to figure out a way to make it not affect you so much. But I'm not very good at that. [You'd say dealing with stress is an issues as far as work for you.] Yes, I don't have a lot of real conscious ways I deal with it. I probably have ways I deal with if Just don't know if I can. It goes along with your thought processes. Don't worry about it. You go home and forget about it. Get yourself involved in something else do you won't think about it. Go out with your friends, go for a walk. Sometimes walks aren't good, because you start thinking about work unless you are walking with a friend and talking about something else. (Irene 03:7)

I don't know if there is a way because things have to be done. Maybe finding a better way of managing my time, learning to work in parallel better. I do that somewhat. [By working in parallel, you mean what?] Doing different tasks at the same time. [Multitasking?] Yes. It is a fairly hard thing to learn to do. In software engineering it is hard to work on multiple programs at the same time or even having tasks on the same computer in different windows. But trying to do them at same time is hard because when you are writing software you need to really get into it. You have to get into the program to figure out how you are going to do this certain thing. It almost requires your whole brain to do that, to keep track of what you were doing over in this program at the same time, it is difficult. I don't know. I don't know what the best way would be of relieving stress. Give me more gum. I chew ice a lot too. (Jeff 03:7)

Two participants did not believe stress levels could be reduced:

I don't think you can. I think it is the nature of the business. There has to be some level of stress otherwise we will be like we were with no growth. Actually, even when we had a lot of people, there was stress when we were just looking at each other saying well he doesn't pull his load, look at him standing around. It creates disharmony. I think this is a more healthy stress. I like it now because it is a more positive stress. (Charles 03:7)

I think if I wanted to or [person] wanted to, we could come in all week and not do anything if we really wanted to. It would drive me crazy. So I think it is our own stress. No one would really come down on us and say you aren't doing this. They treat us like professionals....We are really lucky because our manager is a real bottom line guy. [So the stress reduction here is being able to control your own projects and implementation?] Yes. (Daryl 03:7)

Two of the participants did not believe there was a way to reduce stress and that stress in the workplace was a healthy kind of stress that motivated them to get things done. The other participants had specific ways to reduce stress in the workplace. The participants believed they were capable of dealing with the stress in their workplace through exercise, listening to music, negotiating with people about getting things done, forgetting work and doing something else, or changing the way work was done.

Company Involvement in Stress Reduction

The participants were also asked, "How does your employer help reduce stress related to your work?" One way the company reduced stress was by allowing the participant to make decisions related to his or her job.

They are willing to spend the resource to put the schedules together. They are willing to put the bids together and involve engineering....We do have a system that causes stress. It is called just in time purchasing. We've renamed it "just in late purchasing."...[So one way the company reduces stress is involve you in the decision making process and one way they increase stress is not involve you in the process.] I'd say yes. (Adam 03:8)

The company also attempted to make the environment less stressful:

They put in white sound to cut down on the intelligent noise levels. We have white sound generators and they can control the volume. We used to have it quite loud but one guy complained about it years ago. He said he had perfect pitch and it was extremely grating on him to hear that sound. (Brent 03:8)

They have made a nice environment though. They have break areas and that is nice to go in and you can sit down if you want. They have chairs and tables in there. I usually don't sit down in there. I usually go in there and get a candy bar, ice and water, or a drink or something. They have done a good job in having those break areas. The company I worked at before didn't have break areas. They had candy machines out in the hall, but they didn't have these rooms set aside for break areas. That's nice. They will let us listen to music which can be calming somewhat. I got a Walkman for Father's Day so I listen to music more than I used to. (Jeff 03:8) Although the management of the company attempted to assist employees in

reduction of the amount of daily stress in the workplace, the departmental managers

also provided needed assistance when the problems became overwhelming:

If it gets overwhelming, our manger will jump in and solve problems for us. He is really good about that. [Is there any program that the company has that you are aware of?] They have a library of tapes you can check out. How to deal with teenagers, stress, conflict, different things. The company runs people through conflict management techniques. (Charles 03:8)

I know from personal fact that my managers are doing their best to make sure I'm not over tasked. They have developed a really neat ability over the last year to say no... [The program management office] used to be the gods and whatever they said, went. If that meant you put in over x number of hours a week, then that was expected... That has changed because the layoffs were as drastic as they where, the supervisors and database manager were forced to say no. Instead of trying to do everything, they have cut back and are more effectively managing their time. By default, that means program managers don't get things done.

When one supervisor I know is approached by a program manager to do something, he will say, "We can do that. Which of the following projects do you want to slip? This one, this one?"

"Well we can't slip any of them."

"Well OK. We will work on the one that is the most important to you right now. So you need to make the decision about which one is going to get canned." (Glen 03:8)

It depends on the person you are dealing with. I have a good immediate boss and supervisor who are good about not creating really stressful situations. [How do they not do that?] I don't know, they tell you to do the best you can and don't worry about it. If it doesn't work out, if this problem can't be solved in this amount of time, where it can't be solved period, they make you feel like do what you can do. A lot of times you can talk to them about some situation and they will try and do something about it. If it is an issue with the program office, like a deadline, they will get a mediator to help you along. I've had a situation where I've got a program engineer who wants a certain type of work done on some software I'm responsible for and my own immediate group is a user of the software and they both need things done to it and they both want different things done. I've gotten caught in the middle of a situation where they both were coming to me to get certain things. So I finally went to my boss and said somebody has got to determine what to do, this guy's stuff or this guy's stuff. My boss is really good about setting up some meetings with the two parties and determining what the priorities were so I didn't have to deal with figuring out what to tell both groups of people. I just said this is what my boss said to work on and you will have to live with it or go talk to him. (Irene 03:8)

The upper management tries to stagger your work load. They won't throw everything on to you at once. Sometimes you will have problems come up that you don't have any control over. The company does try to find a way of staggering your work load so you only have one thing to do at a time. It doesn't always work out that way. (Jeff 03:8)

The company provided externally-run counseling programs:

[Is there any program that the company has that you are aware of?] They have a counseling service you can use if you need it. They have an ombudsman program you can call and talk about anything at work that is really bothering you. (Daryl 03:8)

I guess by being very supportive of people's lunch time exercise activities. Oh, they also have the program I just found out about. If you feel like you are having problems and you need someone to talk to, they have this employee assistance program and they will pay \$50 a visit to talk to a therapist if you want to. [Who is that program run through?] I don't know. I have the card at my desk. I think it is just called the Employee Assistance Program. [Just a company that does the work?] Yes, we contract through them and any one who has a problem can go and talk to them. Any kind of problems...marriage problems, alcohol problems, any kind of problems. They will pay for up to eight visits per year per problem. So if you have a couple of different things...[You can have either work or personal problems?] Yes and that is separate from our health care. (Freddie 03:8)

The company provided achievement rewards to promote the feeling that

employees were valued. Although this may have been an effort to improve the morale

of the personnel, it is questionable if rewarding employees to worker harder was

actually a form of stress reduction:

They actually did start a program here several years ago that they call Extra Step, where they actually award you a hundred dollar bill and a little note they print off that thanks you for an effort above and beyond the call of duty. At least it is in the right category of warm pat on the head. It doesn't reduce stress but at least helps you once it is over... Otherwise, there's the previous [bosses], after you had killed yourself, you were still alive and the [item] worked, they gave you two weeks off with pay besides your vacation, sort of as a reward for having killed yourself. Anybody who's chip didn't work, had to come back during that two weeks and figure out why. They recognized there was no way you could get enough comp time to compensate for it or anything, so here's this block of time. But to reduce the stress while it is happening, they don't make any real effort. (Earl 03:8)

As far as the company, I guess a stress reliever for them, that they think they are doing, and I'm not sure how it effects other people, we now have quarterly all-employee meetings. We've had about six of them. We just had one in July. Each time we have one, they give us some kind of a token as a thank you for our work. They express appreciation. This is different from the way things used to be where everyone just innately knew they were appreciated, when it was the family. If you weren't [appreciated], you were asked to leave.

The first year after the lay-offs, it was really hard because people felt they were nothing. It was the bottom line and people didn't matter. But I think that is changing. They are putting more effort into showing their appreciation. I have had Extra Step Awards this year, which has made me feel wonderful.

[What is an Extra Step Award?] It is recognition for an extra effort that you put in. Anybody can recommend anybody for an extra step award. It used to be they were given out very sparsely and I think they have increased the number of awards. It is a small monetary thing. For me, the recognition was better than the money. [How did they recognize you?] In the old days, if you got an Extra Step Award you were supposed to keep quiet about it. It was just for you. You were supposed to keep quiet because they didn't want to make anyone else feel bad. They have changed it now to where the last one I got they did it in front of the entire department of about thirty people. I thought that was really cool. For me it was a really warm feeling because everyone knew I did something good. It is less closed up than it used to be. They want people to know these things are available out there. If you work a little bit harder, just the recognition, just the thank you, hey we did this, we know what you did. Rather than rolling on from day to day with "Gosh, I think I did a pretty good job here but nobody noticed." There is a big difference there. Kudos help a lot. (Heide 03:8)

In summary, participants reported Innova attempted to reduce stress through

providing counseling programs, a pleasant working environment, and rewards for task achievement. The support and assistance from managers also gave participants a sense of relief and accomplishment in completion of tasks and meeting deadlines.

Summary and Discussion of Findings on Stress

The participants in this study did feel stress, both mentally and physically. The reactions of participants to stress were similar. The type of job did not make a difference in the type of reaction to stress: sleeplessness, fatigue, headaches, nervousness, etc. The differences arose in what caused the stress reactions.

In determining that a task was completed, there were both similarities and dissimilarities between the two primary categories of engineering jobs. Both groups used task tracking methods. However, there was a subtle difference in when the participants perceived a task to be completed. The hardware engineers assumed that a task was done when "it works." That assumption had a different bias than the software

engineer assumption that "it works when I think it does." It is uncertain if that underlying difference between these two assessments of the criteria for task completion was related to the type of product or differences within the departments for testing and final delivery of products. However, it did tend to create a type of stressful reaction for the participants with software-related job tasks.

There were three types of deadlines: customer driven (external deadline), management driven (internal deadline), and employee driven (personal deadlines). The process of setting a deadline was guided by the customer needs and management. Setting the deadline was a negotiated process, outside the range of responsibility of the individual participants. However, it also created a team environment for completion of the overall project. The need to complete a task so another work group could work on their task also created a type of stressful reaction. Hardware engineers worried about forgetting critical details or not getting a task completed that would hold up other people. Software engineers worried about not catching a bug in the software that would later show up and crash the image generation system at a critical moment.

The participants defined stress as arising from external sources such as deadlines, trying to get everything done, or trying to accomplishing tasks in short or impossible time frames. One participant described the creation of his stress as "the illusion of necessity." This was the perception that only he could perform a task, and if the task or project was not completed on time the entire company would feel the consequences. The majority of the participants believed the interacting with other people and a lack of time were the primary sources of stress in other employees. Whether the stress was coming from external or internal sources, the common element seemed to have been a lack of control over events. This is a type of stress factors that most closely matches the category of job demands/control factors that have been linked to elbow injuries by previous research (refer to table 2.3). One additional stress factor

was also commonly reported: interaction with people in the form of interruptions or excessive contact with other people. This stressor matches a social factor found to indicate potential injury to hands and wrists.

The reported physical symptoms of stress in the workplace included headaches, physical tension, pain in the neck, the need to eat, panic attack symptoms, and nausea. The reported mental symptoms included worry, self-doubt, tiredness, lack of mental focus, irritability with other workers, inability to sleep, anxiety, and dreams.

Two of the participants did not really believe there was a way to reduce stress and that the stress in the workplace was a healthy kind of stress that motivated them to accomplish tasks on time. The other participants believed they were capable of dealing with the stress in their workplace through exercise, listening to music, negotiating with people to get things done, forgetting work and doing something else, or changing the way work was done. These employees actively sought ways to reduce or deal with the stress in their work environment rather than passively reacting to the effects of stress.

Participants reported the company provided both external and internal programs to assist them with stress reduction. Also the support and assistance received from their managers gave them a sense of relief and accomplishment in completion of tasks and meeting deadlines. The active involvement of Innova in providing support programs gave a sense of positive psychological support to these participants. However, it is unclear if it aided in overall reduction of injury at Innova.

Appropriate skills for reduction of stress that may lead to injury in this workplace may include those strategies that would allow the employee to: (1) react in an appropriate manner to situations that are beyond their control, (2) find ways to complete job tasks in short periods of time, (3) find ways to meet deadlines within the assigned time frames, and (4) reduce the stress associated with interacting with people.

Summary of Findings

This chapter has delineated the findings of this study. The areas of importance were related to job tasks; hardware and software tools; workstation design and knowledge of ergonomics; and stress factors in the workplace that may cause injury. The findings will be discussed within the context of the guiding questions in the next chapter.

Tasks and Tools

Findings for hardware and software use indicate:

- Literacy for tools usage is both a functional process and a type of knowledge.
 - a. It was a functional process because it consisted of a series of continuous actions, operations, or series of changes taking place in a definite manner over a course of time. The process used by the participants to gain and retain job skills was through self-instruction and applying skills on the job.
 - b. It included types of knowledge that defined the basic job skills.
- 2. The job skills of tool usage at Innova were defined as being able to:
 - Turn a computer on and use common, commercially available software applications (i.e., word processing, spreadsheet, database, and programming languages).
 - b. Understand the software applications well enough to perform nonstandard usage of software features to solve daily problems.
 - c. Understand and be able to use multiple types of operating systems and networks (i.e., UNIX, MS DOS, MS Windows NT).

- Use oral, written, and visual methods to communicate information to other employees or customers about the design, production, debugging, testing, documentation, and implementation of technology based products.
- e. Set up software and networks to accomplish job tasks.
- 3. It would be valuable for students to be taught the above mentioned job skills as well as strategies for effective self-instruction, strategies for analyzing tasks to teach others, and effective oral, written, or visual communication skills.

Workstation Design and Ergonomics

Findings about workstation design and ergonomics indicate:

- The participants in this study were intensive computer users with continuous contact with computer equipment and furniture yet reported no chronic pain or health problems from the usage of computers or from the configuration of their work areas.
- 2. The participants also had little or no ergonomic training in setting up a work area nor did they have a technical knowledge of the items related to ergonomic positioning of people and furniture. However, the second interview generally indicated they had an experienced-based knowledge of these items and used that experience to rearrange their work areas.
- 3. The first line of defense in the company for reduction of injury was correction of possible problems in the physical layout of workstation areas. The company provided a suggested plan for arranging the work area that the employees tended to keep.

- 4. The participants were aware of their unique physical dimensions and the need for adjustments for height and distance in their hardware or furniture. However, the participants were not acting with any focused purpose in altering their work area other than changing things if they were already experiencing pain.
- The OSHA Assessment Form identified areas of lack of easy adjustability in furniture; however, furniture could be modified with assistance from the physical plant personnel.
- The OSHA Assessment Form identified a lack of training on how to identify risk factors that may led to injury.
- 7. Injury in this workplace (i.e., carpal tunnel syndrome, sore wrists, and muscle strain or tension) was not understood to be injury in the sense of a sudden accident, but rather was viewed as weaknesses or a problem that could be corrected by changing furniture height, placement of equipment. Participants also believed carpal tunnel syndrome was an illness that could be managed or cured by going to a doctor.

Stress Factors

Findings about stress factors indicate:

- There was a subtle difference in how the participants perceived a task to be completed. The hardware engineers assumed that a task was done when "it works" and the software engineers assumed that a task was done "when I think it works."
- The process of setting a deadline was described as *interlinked* because of the interaction between the people and the needs of the customer. Setting the
deadline was a negotiated process, outside the range of responsibility of the individual participants.

- The participants defined stress as arising from completing job tasks, meeting deadlines, and interacting with people.
- The majority of the participants believed interacting with other people and a lack of time were the primary sources of stress in other employees.
- 5. Whether the stress was coming from external or internal sources, the common element seemed to have been a lack of control over events.
- 6. Job control factors influencing computer-related injury (see table 2.3) were present in this workplace (i.e., lack of productivity standards, increasing work procedures, limited breaks, routine work lacking decision-making opportunities, surges in workload, and extensive overtime). However, none of the participants had reported or experienced computer-related injuries any time in the past.
- 7. The reported physical symptoms of stress in the workplace included headaches, physical tension, pain in the neck, the need to eat, panic attack symptoms, and nausea. These physical symptoms indicate there should be a reported incidence of neck, cervical, shoulder, hand-wrist, and lower back injuries among these particular employees (see table 2.3). However, there were no significant reported incidences of injury in these employees.
- The reported mental symptoms included worry, self-doubt, tiredness, lack of mental focus, irritability with other workers, inability to sleep, anxiety, and dreams.
- The participants took an active approach to dealing with the stress in the workplace through exercise, listening to music, negotiating with people to

get things done, forgetting about work and doing something else, or changing the way tasks were done.

- 10. The company provided externally run programs to assist employees with stress reduction. The support and assistance received from managers gave the participants a sense of relief and accomplishment in completion of tasks and meeting deadlines. The company also provided awards for employee performance. However, it is unclear if the active involvement of Innova through providing stress reduction programs aided in overall reduction of injury.
- Appropriate skills for reduction of stress that may lead to injury in this workplace would include those strategies that would allow the employee to:

 (a) successfully cope with completion of tasks in short periods of time, (b) deal with meeting deadlines within the assigned time frames, and (c) handle interaction with people in a non-stress-producing manner.

CHAPTER 5

CONCLUSIONS AND IMPLICATIONS

Introduction

A qualitative study of a workplace was conducted in the summer of 1996. The study consisted of interviews and observation of ten participants who were working in hardware engineering and software engineering positions. The study arose from a lack of information on functional needs for computer usage and the resulting lack of identified skills and knowledge needed for safe, efficient work with computing systems.

Three primary questions guided this study. The first question assessed the components of the job task model (job tasks, tools, and environment) as a basis for defining the areas of computer literacy for the individual worker. The second question assessed how the job task influenced computer usage in the areas of training, hardware and software usage, application of individual anthropometric data, and workstation design. The third question explored the types of stress factors found in the workplace.

Guiding Questions

The following section provides answers to the guiding questions based on the compiled findings of this study. Refer to Chapter 4 for the summary of findings of the study.

The Job Task Model, Guiding Question 1

Does the job task model define the areas of computer literacy for the individual worker? During the design phase of the proposal for this research, it was decided to utilize the job task model as a means to guide data collection. Previous research in the area of computer literacy had not been guided by a model for workplace settings but by models based on academic theories or hypothesized skills for computer usage. The job task model proved to be a viable instrument for defining needed areas of computer literacy in the workplace. The categories within the model are: types of task, types of tools, and types of environments where computers would be used. The following sections provide a summary of data found in the three categories within the job task model.

Tasks

What tasks are generally performed daily?weekly? monthly? other? The task element of the job task model defined the content of the work and the associated skills and knowledge described by the participants during the interviews. These daily and weekly job tasks identified the following tasks as important to all of the participants: the ability to program a computer to perform various functions, the ability to solve problems, the ability to define needs, the ability to document products, the ability to work on a team, and the ability to learn to use new technologies or methods.

Daily tasks included those specific to proposing, designing, and developing products; meeting with members of product development teams to solve arising problems; and the daily review and reporting associated with tracking of projects or solving problems associated with projects. The weekly and less than weekly tasks included tasks such as meetings with team members, finding and eliminating problems associated with products, creation of documentation, review of products before final release, and providing engineering support to in-house projects or to customers. The timing of tasks varied between individuals and were linked to natural cycles of production associated with deadlines.

Tools

What tools are generally used in performing this job? The tool element of the job task model defined the types of computer hardware and software required to perform

tasks. Tool-based skills and knowledge were identified through answers to the Hardware and Software Usage Questionnaire. The types of tools were divided into two categories: professional tools and general technology tools.

The general software tools used included operating systems for a variety of computers, word processing software, spreadsheet software, database software, presentation software, network software, and utility software. The professional software tools included computer-aided design software for drawing schematics or designing circuits, programming languages, and specialized types of databases (e.g., Oracle). The associated knowledge and skills identified for using software were the ability to correctly and efficiently use each piece of software as well as the ability to learn how to use new types of software.

The general hardware tools included external and internal data storage devices, general input devices (e.g., keyboard, mouse, electronic pens) and peripheral devices (e.g., monitor, external data storage devices, videodisc player, scanning devices, or CD-ROM drives). The professional hardware tools included network cabling and image generation equipment. The associated knowledge and skills identified for use of hardware were the ability to access and operate the devices and rearrange and reconnect them as needed.

The professional-level employees needed to know how to use both the general software and hardware tools as well as the specialized hardware and software tools of his or her trade. For example, a hardware engineer would use specialized CAD software to draw schematics or use a digital analyzer to find a problem with the flow of data through electronic components in a computing system and then create a report using general purpose word processing software that would be distributed to appropriate sources through the LAN network.

All of the participants had been trained to use the specialized tools of their trade but none of them had received specific instruction in the use of general software (e.g., word processing, spreadsheet, database, or network software). This was an area of training that was suggested by the participants for inclusion into existing academic courses. All participants had to know how to operate the general software in order to efficiently perform their jobs and yet there were no courses offered during their academic training that prepared them for this type of task in their future professional lives.

Workstation Environment

What is the workstation environment for the job tasks? The environmental element of the job task model described where the task occurred and what tools were used to perform the task. The environment was delimited by the appropriate tools needed to perform assigned tasks and the furniture needed to support the tools. The workstation environment was found to be an important element in the safety associated with daily work routine because that is where employees spent long periods of time in contact with computers. Workstations consisted of equipment components placed in an assigned area that had adjustable walls and furniture components. The workstations contained furniture that was adjustable for employee height and placement of hardware components. It was found that a standard configuration of furniture and equipment suggested by the company did influence how the equipment was arranged and as a result, how employees performed their daily job tasks.

In summary, the job task model used as the foundation for this study indicated areas of potential need for training in technology-dependent professions. The model is appropriate for instructional design purposes to identify and define the tasks, associated tools, and appropriate work environments in professions that require the constant and systematic use of technology. The model also provides a method for linking the various

academic content areas through an understood hierarchy of relationships (i.e., how the job task specifies the type of tool to be used that in turn delimits the environment where the job task should most optimally be performed). Refer to the job task model, Fig. 2.1, a representation of the job task model.

Influence of Job Tasks on Needed Skills and Knowledge, Guiding Question 2

Does the type of job task influence the functional needs for computer usage in the areas of training, hardware and software use, individual anthropometric data, and workstation design? It was determined that the type of job task defined the hardware and software tools needed to perform a job task. Those tools, in turn, influenced the arrangement of the work areas. The experience gained from using computer equipment did influence the individual's awareness of his or her environment and the resulting decisions for arranging the environment to fit his or her physical dimensions. However, the type of job task did not influence the way training was gained.

Computer Usage History of Employees

What is the computer usage history of the employees at the workplace? The process of becoming computer literate emerged as an important aspect of the study because it was a continuing process in the workplace. It was determined that the participants were primarily introduced to computers in academic settings (eight of ten participants). However, they were not taught the general usage of computers by an instructor in a classroom but rather learned to use computers through self-instruction and use of supplemental materials such as manuals or on-line help. Academic instruction focused on specialized knowledge specific to the chosen discipline (e.g., programming, designing computer chips, or how to design a visual display monitor).

The predominant method for staying current in the use of new software and hardware technologies was also through a self-instruction process with assistance from other employees and usage of supplemental materials (i.e., books, on-line help, examples of correct code to emulate if needed). The extensive use self-instruction strategies by computer users indicates a need to teach appropriate study skills for self-instruction. It is uncertain if study skills for learning about technology would be identical to study skills applied to text-based instruction.

Training for Software and Hardware Usage

What specific training on software and hardware usage is required in this workplace? The findings indicated the job task at a professional level guided the need to use general and specialized software and hardware. Functional skills were determined to be the ability:

- 1. To efficiently operate a computer system to access and store data files.
- 2. To use multiple operating systems (UNIX, real time, Windows, and DOS).
- 3. To customize software preferences as needed to perform job tasks.
- 4. To perform programming tasks.
- To stay current with both software and hardware specific to the area of expertise.
- To effectively use basic software applications (word processing, database, spreadsheet, and presentation software).
- To effectively use specialized software applications (e.g., computer-aided design software or programming languages).
- 8. To set up hardware equipment as needed to perform necessary job tasks.
- 9. To access information over a network and recable the network if required.
- 10. To attach peripheral hardware devices for test or demonstration purposes.

There was a need to know how to set up professional equipment (e.g., testing equipment, circuit boards, and networks); but, ironically, there was no need to understand how to set up the hardware to use in the assigned workstation. Support personnel performed all necessary maintenance and upgrades on computer equipment and software in the assigned workstations, thereby freeing the employees of that task.

Designing the Work Area

What job factors are most important for the participant to understand in designing the configuration of his or her work area? There were two factors that influenced workstation layout. Those were job tasks and the associated tools needed to perform the tasks. The participants reconfigured their work areas when they received new equipment or changed the type of task they were performing. They also reconfigured the shared hardware/software testing area when electronic components were being changed in the image generation equipment to allow evaluation of products.

The type of job task specified the type of equipment, which in turn determined where it was placed in the work area related to other equipment, power outlets, and the task to be performed. Also the company provided a prearranged configuration of the workstation area based on ergonomically designed floor plans.

Another factor that should influence workstation layout according to the reviewed literature was a knowledge of risk factors associated with injury. However, the employees had no training or understanding of those risks and therefore, only reconfigured their workstations if they were experiencing discomfort or felt they could improve the way they performed job tasks.

Anthropometric and Ergonomic Principles

What anthropometric and ergonomic principles are most important for the participant to know and apply to individualize his or her work area? The review of

literature indicates the adjustment of the chair, keyboard, and monitor height are important elements in the overall ergonomic considerations for a workstation (Atencio 1993; Carter and Banister 1994; Pheasant 1991; Tessler 1994). The findings of this study indicated that the most common cause of readjusting furniture was to eliminate discomfort. However, the results of the Ergonomic Concerns Quiz indicated eight of ten participants lacked an understanding of how to correctly adjust these key components in a workstation design.

It was found that an understanding of how to set up the equipment and furniture in the workstation area was based on the participants' experience from use of computer equipment—not from formal training in ergonomic principles. For example, they understood that the type of chair they were using had characteristics that they either liked or disliked but they did not understand how or why to adjust the chair to provide appropriate support (e.g., they liked how the chair felt when they sat in it or they disliked the chair because it could not be adjusted or it could not roll around when they were performing different tasks).

Even though the participants attempted to correct uncomfortable or painful situations they believed were caused by improper adjustment of their furniture or hardware, they did not know what was causing the uncomfortable conditions. The equipment position modified most frequently was the position of the keyboard and the monitor height. Keyboard trays were not added to the workstations to provide ergonomic adjustment. Keyboard trays were used to move the keyboard out of the way when it was not being used. Chair height was important to the participants, but once it was adjusted, they did not modify the height.

An understanding of the causes of various types of pain or injuries would be helpful for computer users to have in order to guide their choices on adjusting their workstation environment. It would also be useful for each person to have knowledge of any variation he or she may have from the anthropometric standards used to design

computer furniture and hardware components. This would allow the individual to make informed decisions about how to set up or modify the work area to compensate for his or her unique needs.

Stress Factors, Guiding Question 3

What are the stress factors in this workplace setting? The participants in this study reported a variety of stress factors related to the job tasks and the workplace environment. Those stress factors included job demands and social or interaction demands on the workers.

Stress caused by job demands was created by the workload in general, surges in workloads, deadlines and associated task completion crises, and extensive overtime. Stress caused by social factors were also indicated by the participants. Social factor stresses (psychosocial factors) are caused by disruptions that create the individual's inclination toward or aversion to events, objects, and other individuals (Fishbein and Ajzen 1975; Gredler 1992). The psychosocial factors found at this workplace included worry about personally meeting deadlines, worry about forgetting critical components of tasks, worry about a lack of job skills, and worry about the future impact of technology on an employee's continued economic welfare.

The participants' physical stress symptoms included general fatigue from noise, visual fatigue, headaches, muscle tightness (general and in shoulders and back), neck discomfort and pain, sleeplessness, canker sores, increased heart rate from anxiety, nausea, and diarrhea. The mental stress symptoms included worry, a wandering mind or fuzzy thoughts, irritability or a shortness of tempter, anxiety, self-doubt, panic, and dreams about work (refer to table 4.9).

The findings indicated that participants reacted to job-related stress with what appeared to be different levels of anxiety (e.g., physical anxiety in the form of nausea,

physical and mental anxiety in the form of sleeplessness, or purely mental anxiety in the form of self-doubt). The participants indicated that the situations they could not control were generally the most stress producing (e.g., deadlines, technical difficulties, actions of other people).

Stress and Injury

Do the stress factors influence computer-related injury in this workplace? None of the participants in this study had reported computer-related injury even though they had several types of risk for injury. The sample size of this study was not intended to generate statistically generalizable data but rather to understand the phenomenon being studied. As a result, information was gathered that provided verification that the stress factors previously found to be linked to computer-related injury (i.e., long-time computer users, lack of regular breaks, extended time working at a keyboard, surges in workload, unstable deadlines, extensive overtime, and mental and physical fatigue arising from stress) were present in this workplace although the participants did not react to the stress factors with verified incidence of injury.

Previous research on injury indicates that the stress arising from job demands could eliminate or reduce the workers' rest cycles and increase the risks for injury (refer to Fig. 2.2, injury cycle). The types of reported psychosocial factors may create a type of mental pressure that causes the worker to work beyond healthful limits (Carter and Banister 1994; Cohen, Kessler, and Gordon 1995; Pheasant 1991; Sauter and Swanson 1996; Smith 1987). It should also be noted that the most troublesome causes of stress (i.e., deadlines, technical difficulties, actions of other people) were found throughout the company, not just in the participants' work areas. The lack of reported injury of the participants may have arisen from personal resilience or from stress reduction techniques used by the participants or those promoted by the company.

Reduction of Injury

If there were stress-related injuries, how can those types of injury be reduced? As stated above, none of the participants in the study had reported computer-related injuries. It is difficult to predict if any of the reported stress factors would eventually lead to injury in the participants. The data in the study were insufficient to determine if any of the stress reduction activities of the participants or employer had any lasting effect on averting or reducing the potential for injury. Verification of a reduction in stress levels would best be determined through a longitudinal study but could not be verified in this study.

The participants used a variety of methods to reduce their stress levels. This included exercise outside of work, getting away from the job, and talking to supervisors to request assistance. The management of the company was tolerant of employees taking time away from work to exercise (walk, run, swim, play golf, etc.). Also, the company provided employees with external programs (e.g., counseling) and internal programs (Extra Step awards) and training on crisis management to promote a positive workplace.

Other Findings

Other areas were identified for areas of training in technology-based professions. These areas included a need for communication skills in general, a need to know how to training other people, and the need to understand the pathology of an injury occurring over a long period of time.

Communication Skills

Projects span months and perhaps years of time in workplaces. This factor does not allow one person to perform tasks in isolation. Projects in technology-based workplaces are massive and involve many different processes and types of jobs. This creates an increased need to communicate abstract ideas and concepts to other people through multiple modes of communication (written, oral, and visual). All of the participants had to prepare written documentation for the products they designed. Some of the job tasks required visual representations of processes or products that could be used to communicate information to other people. The participants also regularly met with members of their project teams or managers to discuss various aspects of design and production. Proficiency in various modes of communication appeared to be a needed skill in an information intensive workplace.

Training Provided by Employees

Besides training themselves to use new technologies, participants engaged in training other people (peers and customers) to use software. The participants assisted peers in setting up their software (UNIX operating system) and showed new employees and customers how to use various types of software. Training other people to use products is an extension of the communication skills that are need to create and design products.

Accidental Injury Versus Accumulative Injury

This finding arose from the data that suggested the participants did not think there was any injury they would incur at their jobs. However, they all reported carpal tunnel syndrome was a problem for people who typed for long periods of time (e.g., a secretary). They also apparently did not think of carpal tunnel syndrome as a type of reportable injury in the sense that it did not occur abruptly.

The perception that computer-related health problems were not a type of reportable injury may have been because the types of health problems associated with use of computers develop over a long period of time rather than occurring abruptly like an accident would occur. The company did have established procedures for reporting accidental injuries (i.e., abruptly occurring injuries). The procedures were posted in all of the break rooms and available on bulletin boards throughout the company and in manuals given to employees. However, there was no evidence of posted information about symptoms or risk factors that may cause computer-related injuries. This may have contributed to the attitude that there were no risks for injury associated with the usage of computers.

Implications Arising from the Findings

The findings of this study indicate there is a need to understand not only how to set up and use computer software and hardware but also how to create an effective, healthful work environment. The complexity of a technology-intensive workplace requires a balanced approach in providing information on the usage of computers.

Prior to the computer revolution, machinery was not seen as an extension of the human mind but rather as an extension of a process. The French sociologist Jacques Ellul termed the process of using technology as *technique*.¹ He believed that

[I]t is the machine which is now entirely dependent upon technique, and the machine represents only a small part of technique. Not only is the machine the result of a certain technique, but also its instructional applications are made possible by technique. Consequently, the relation of behavioral science to instructional technology, parallels that of the physical sciences to engineering technology, or the biological sciences to medical technology. (Saettler 1968, 5-6)

In the instance of computer technology, the technique of computer usage requires teaching skills and knowledge for the methodical usage of the software and hardware. Technique also applies to setting up the environment where the computer is used. The line between the technique and the task is no longer clearly defined because the task requires an internalized, human interaction *with* the computer environment rather than an externalized reaction *to* a mechanical environment.

¹Technique is defined here as a specialized process or method for accomplishing an action.

Computer technologies differ from mechanical technologies in the amount of mental interaction between the worker and the machine. In this study, this difference was identified in the two different engineering groups. The hardware engineers utilized computers as tools but still worked directly—hands on—with the electronic components they designed. They would locate the product on an assembly line or attach the component to a... test frame to locate problems. The product of their labors was external to themselves. On the other hand, the software engineers could not touch any part of their products because those products only existed in their mind and in the memory of a computer.

Another emerging trend that affected how the engineers worked was the process of miniaturization. The electronic components were becoming so small and complex that the engineers could no longer see or manipulate the components. This was forcing the hardware engineers to find new ways to design the components as well as isolate problems within the components when needed. They were becoming software dependent in performance of tasks that they may have been trained to do with methods not dependent on computers. For example, the engineers may have been taught to hand draw a schematic for a component on a piece of paper but they were now doing the schematics with the aid of CAD software, or the engineers may have been trained in how to attach a probe to a wire on a circuit board to test a circuit but they were now performing analysis of circuits with the aid of software programs.

This interaction between a machine and the human mind creates a psychosocial dimension of interaction. It also indicates a change in the way instructional content should be analyzed and organized. The linear, instructional design model for the mechanical products of an industrial revolution no longer adequately illumines the instructional content of information processes and related technologies. What is needed is a model that explains the interaction of the various components of information processes.

A social process triangle model is an interactive, information processing model. It was first proposed as a conceptual framework for studying the balance between the foundational aspects, organizational aspects, and meaning-giving aspects of an activity. These three aspects form a triangle of poles of activity within a social structure. The social process triangle has been used to identify dysfunction between any of the parts of the triangle that may be causing a weakening of the overall process. According to Ahearn and Crocker, an imbalance in any part of the process causes one aspect to become dominant and the others to become subordinate and nonfunctional (Ahearn and Crocker 1995). This imbalance can be see in existing approaches to computer literacy. Software usage training dominates the curriculum to the exclusion of other information needed to create a balanced approach to the use of computers.

The job task model is a type of process triangle that identifies the various components of a task in a workplace. The job task must also maintain a balance of activities or it will collapse and cease to be productive. The hardware and software tools create the foundational aspect of the job task model and are inseparable—you need one to use the other. Tools are the vehicles of activity. The environment creates the organizational aspect of the job task model. It provides the means to organize and effectively use tools to perform a task. The task itself creates the meaning-giving aspect of the job task model. It is the job tasks that give purpose or direction to the tools uses and also delimit the place where the task occurs. Like the social process triangle, the job task model requires balance between the three poles or areas of influence to maintain an efficient, healthful work environment.

This study provided evidence that the job task model is an effective means to organize categories of activities related to those professions associated with computer usage. This study also provided evidence that an imbalance created mentally and physically stressful conditions and created a potential risk for injury (e.g., a lack of

knowledge of how to use tools resulted in an inability to correctly and efficiently perform tasks; a lack of knowledge on how to set up the work environment resulted in an inability to correctly and efficiently perform a task or resulted in a potential risk for injury).

Using a job task model to reanalyze the reported studies on factors that may cause computer-related injury (refer to table 2.3) indicates the existence of imbalances between the poles or categories within the job task model. For example, injury factors related to job demands may arise from an imbalance between the task and tool because the improper tool is used to perform a task. An imbalance between the task and the environment may cause injury because the task is being performed in an inadequate or non-supportive environment for that task. Likewise, injury factors arising from a lack of ergonomics are created by an imbalance between the environment and the tools or between the tools and the task. The injury factors associated with psychosocial factors could arise from an imbalance in an environment where people have a high degree of contact with other people thus reducing their ability to perform a task.

Design of instructional products related to computer usage requires an understanding of the interaction between the categories of activity in the job task model. The content of computer literacy training in academic settings has heavily focused upon tool use (primarily software) for performance of tasks with a total exclusion of environmental factors. The lack of one or more poles in the model would cause weakness throughout the model and would also cause one of the poles to become dominant (Ahearn and Crocker 1995). In the case of computer literacy training, the emphasis on use of software has become far more prominent than any of the other aspects of the model. An appropriate corrective action would be to redesign the instructional content of computer literacy training courses to include the subordinate pole of the task (i.e., setting up and using both software and hardware to perform an action) and the subordinate pole of the

environment (i.e., setting up and using both software and hardware to reduce the risks for injury).

Another implication from the findings of this study is the impact of technology on the K-12 population of students. Although the findings of this study were based on activity in the workplace, there is growing evidence that the young computer users of the 1980s and 1990s are experiencing injury (Karlo 1996). This study points toward an inescapable consequence of providing computers to children or young adults: They are forming future work patterns. The findings of this study indicate that the participants trained themselves to use computer hardware and software when they were students, and, as a consequence, they were lacking in knowledge of risk factors and appropriate work habits that could reduce their potential for injury. This appears to be a common pattern in education with regard to learning to use computers.

This pattern of self-instruction for students to achieve a degree of computer literacy based on their understanding of software usage with the exclusion of ergonomic awareness or practices has already begun to manifest as injuries (Karlo 1996). The question is, as a society, can we afford to allow the oncoming generation of computerusing children to arrive at the workplace already injured from years of accumulated microinjuries or with work habits that may eventually lead to injury? The purpose of instructional design is to promote competency in skills and knowledge in the spectrum of content areas as well as provide a safe environment in which to learn. This must include the promotion of safety as well as competency in the use of emerging technologies.

Future Research

The purpose of conducting this study was to gather data on the lack of information on the functional needs for computer usage and the resulting lack of identified skills and

knowledge needed for safe, efficient work with computing systems. Based on the findings, several areas of future research are suggested:

- The curriculum content for computer literacy training in academic departments should be analyzed to determine how to apply the job task model to specific disciplines.
- Data should be gathered on educational policies and practices to determine the most effective point in the educational process to teach ergonomic standards and promote healthful practices in the usage of computers.
- Existing self-study strategies in non-technology-based environments (i.e., reading text books, self-study modules) should be evaluated for effectiveness in technology-rich environments and modified to meet information technology training needs.

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APPENDICES

Appendix A:

Data Collection Matrix

DATA COLLECTION MATRIX (Continued) APPENDIX A DATA COLLECTION MATRIX FOR STUDY OF FUNCTIONAL NEEDS

Note: The interview probe and questionnaire probe questions in this matrix are found on the forms indicated in the location column.

Research Question	Interview Question # 1	Questionnaire #1	Location
I. Does the job task model define the areas of computer literacy for the individual worker?	02b:4. What kinds of things do you generally do in performing these responsibility ?	02a:1. Rank order these responsibilities in order of what you believe to be importance to accomplishing your job.	Questionnaire: Job Responsibilities and Task, Part 1 (1-3)
A. What tasks are generally performed	02b: 6. Do you interact with other people while performing	02a:2. Rank order these responsibilities in order of frequency.	Interview: Job Responsibilities and
daily? weekly? monthly? other?	this task?	02a:3. Indicate WHERE you perform this task.	Tasks, Part 2 (4-7)
B. What tools are generally used in performing this job?	02b:7. Estimate how much time you spend on an average day on a	02e:(Diagram of arrangement of work area)	Workstation Diagram and
	computer.	01b:2. What kinds of software do you generally use to	Observation
C. What is the workstation environment		do your job tasks?	0
for the job tasks?		01b:5. What kinds of hardware /software do you generally use to do your job tasks?	Hardware and Software Usage
		01b:6. What are the various components on this system?	

¹ The coding indicated with the interview and questionnaire items indicated the form where the question may be found. Refer to Appendix B for coding.

DATA COLLECTION MATRIX (Continued)

Research Question	Interview Question #	Questionnaire #	Location
II. Does the job task influence the functional needs for computer		01a:1. When do you first remember being introduced to computers? (age, location, condition)	Questionnaire: History of Computer Usage
usage in the areas of training, hardware and		01a:2. How did you learn to use a computer?	computer couge
software use, individual anthropometric data, and workstation design?		01a:3. What kinds of things do you remember learning about using computers? (For example, how to program in Basic, how to set up equipment, etc.)	
usage history of the employees at the work place?		01b:4. What kinds and brands of hardware where you trained to use during your time in college?	
B. What specific training on software and hardware use is	02:1. On your questionnaire about learning to use computers, you marked	01a:2. How did you learn to use a computer?	Interview: History/Hardware &
required at a professional level in this work place?	"x" as the primary source of your training. Why was this the most influential source? Is "x" still the	01b:1. What kinds and brands of software where you trained to use during your time in college?	Software/Computer Literacy
	primary way you learn? 01:3. What is the relationship between what you learned in an academic program	01b:3. Are there any kinds of software that you use regularly to perform your job that you think people being trained in your profession should know how to use?	Questionnaire: History of Computer Usage.
	and what you do on your job. 01:4. What is "computer literacy" in your job? What iside of things do	01b:7. Are there any kinds of technology you use regularly to perform your job that you think other people in your profession should be trained to use?	Questionnaire: Hardware and
	employees need to know about using computers to be "computer literate"?	01b:8. Think back to the kind of information you received during your college training. What are the major differences that stick out in your mind between what you	Software Osage
	01:5. Do you ever have to train someone to use software of any kind? What kinds of things do you typically	were trained to do and what you need to do in your current job?	
	teach them?	01b:9. Are there other kinds of training (in areas other than those listed above in software and hardware) you believe	
	01: 7. Do you ever have to train someone to use the hardware you typically use at work? How do new people learn to use the proprietary systems here at work?	people learning about your profession should have? If yes, what?	

DATA COLLECTION MATRIX (Continued)

Re	search Question	Interview Question #	Questionnaire #	Location
C.	What job factors are most important for the participant to understand in designing the configuration of his or her work area?	 02:1. Why do you have your work area arranged this way? Please explain why this setup is best for you. 01:6. Do you ever have to modify the computer hardware you use in your work area? What? 02:5. If I came to you for advice on setting up my work area to do the same kind of job you do, what would you advise me to do? 02b:5. Do you have to rearrange your work area in order to do these job responsibilities? 	02f:Draft Document: OSHA Workstation Assessment Form 02:8. Observation of the kinds of motions performed when operating a computer.	Interview: History/Hardware & Software/Computer Literacy Workstation Interview and Observation Job Tasks Part 2 Interview Draft Document: OSHA Workstation Assessment Form
D.	What anthropometric and ergonomic factors are most important for the participant know and apply to individualize his or her work area?	 02:1. Why do you have your work area arranged this way? Explain why this setup is best. 02:2. Every person has different dimensions. What kinds of things related to your individual physical dimensions effect how you work with computers? 02:3. Do you have a special way you have developed to operate a computer that makes you comfortable when you are working? 02:4. What kinds of injury are common to your profession? Have you ever received any information or training on how to set up a computer work station to reduce injury? If so, what do you remember learning? 02:6. Do you have a regular exercise program? Do you have any specific exercises you do to help prevent computer-related injury? What? 02:7. Have you ever learned any type of exercise for relieving muscle tension while working on a computer or for other purposes related to computer use? What? 	02c:Ergonomic Concern Quiz 02f:Draft Document: OSHA Workstation Assessment Form 02e:8. Observation of the kinds of motions	Interview: Workstation/Task and Observation Questionnaire: Ergonomic Concern Quiz Draft Document: OSHA Workstation Assessment Form

DATA COLLECTION MATRIX (Continued)

Research Question	Interview Question #	Questionnaire #	Location
 III. What are the stress factors in this work place setting? A. Do the stress factors influence injury? B. If there are stress related injuries, how can those types of injury be reduced? 	03:1. How has your job changed in the last three years? 03:2. How are task assigned in your work group? Who assigns tasks? How do you know when you have satisfactorily completed an assigned task?		Interview: Stress Factors
	03:3. How are project deadlines determined? Who determines deadlines on projects? What are typical types of deadlines?		
	03:4. What is stress? How do you define stress? Are there any physical or mental symptoms of stress? Are there other things you notice about stress?		
	03:5. If one of your fellow workers gets really upset at something at work, what usually is the cause of the problem?		
	03:6. What kinds of things are stressful about your job? How do you commonly deal with this type of stress?		
	03:7. If someone where to ask you how to reduce the amount of stress at work, what would you suggest?		
	03:8. How does your employer help reduce stress related to your work?		

Appendix B:

Coding For Participants And Forms

APPENDIX B

Coding For Participants And Forms

Participant Pseudonyms and Coding

Hardware related job, pseudonyms used: Adam (11), Brent (12), Charles (13), Daryl (14), Earl (15)

Software related job pseudonyms used: Freddie (21), Glen (22), Heide (23), Irene (24), Jeff (25)

Codes for Forms

Codi	ng for Form	Form Name
	01	Interview about Questionnaires and Computer Literacy
	01a	Questionnaire: History of Computer Use
	01b	Questionnaire: Hardware/Software Use Questionnaire
	02	Interview on Workstation
	02a	Questionnaire: Job Task Part 1
	02b	Interview: Job Task Part 2
	02c	Ergonomic Concern Quiz
	02d	(Form eliminated from study)
	02e	Workstation Layout/Observation
	02f	OSHA Assessment Form:
	03	Interview on Stress Factors

Appendix C:

Research Chronology

APPENDIX C

Research Chronology

The following listing of events is given as a guide to the chronology of the study.

- Prospective participants were contacted by e-mail and sent an electronic copy of an information form to determine if the prospective participant could be included in the study based on professional job title. The personal data included the job title, age range, highest educational level achieved, graduating institution and date of graduation, program of study, date of employment in profession, date of employment at company, and confirmation of daily computer use.
- After responses to the information form were received, a meeting was arranged with the prospective participant to inform him or her of the proposed study intent and content. The prospective participant was then asked if he or she wished to participate in the study.
- 3. If the employee agreed to participate, a paper copy of the History Of Computer Use Questionnaire and A Hardware/Software Questionnaire were given to him or her to provide time for thoughtful answers before the electronic form was received via e-mail. (Data were gathered through email.) The employee was asked to reply back to the researcher before the next meeting.
- 4. Each participant was asked to take the researcher to his or her work area so the researcher could draw up a quick pencil sketch of the general layout for that work area. The floor plan for the workstation was verified and corrected during the workstation interview.

- 5. After the History of Computer Use and Hardware/Software Usage Questionnaires were completed and electronically transmitted back to the researcher, an interview was scheduled with each participant to clarify points on the questionnaires and to gather information on computer literacy for the specific participant's job.
- 6. After the first interview to clarify the questionnaires and investigate computer literacy, the second interview (job task interview) was scheduled to investigate job tasks, obtain measurement of the workstation, verify the layout drawing of the area, complete the VDT Workstation Assessment form, administer the ergonomics concern quiz, and observe the participant performing routine job tasks. The final interview was scheduled to investigate stress factors related to job tasks and the workplace.
- 7. The final interview was conducted. At the end of the interview on stress factors, participants were asked why they believed they had been assigned to the study. The researcher also asked if the participants had any questions or required any additional information on topics that had been discussed.
- 8. After all data had been transcribed from interviews and observation notes, the data were assembled for each participant and mailed to each participant for clarification and correction. A date for review of the data was set and follow-up messages were sent to prompt responses from participants as needed.
Appendix D:

Interview and Questionnaire Forms

Used in the Study

APPENDIX D

Interview and Questionnaire Forms Used in the Study

Interview: Questionnaires and Computer Literacy (Form 01)

- On your questionnaire about learning to use computers, you marked "x" as the primary source of your training. Why was this the most influential source? Is "x" still the primary way you learn?
- 2. Tell me about the computer facilities available to you as a student.
- 3. What is the relationship between what you learned in an academic program and what you do on your job?
- 4. What is "computer literacy" in your job?
- 5. Do you ever have to train someone to use software of any kind?
- 6. Do you ever have to modify the computer hardware you use in your work area?
- 7. Do you ever have to train someone to use the hardware you typically use at work?
- 8. Is there anything else about software or hardware you think is important to people to know?
- 9. a. Some people think computers should be used to make people more powerful. Other people think computers should be used to facilitate better communication between people and solve problems? What is your idea about the purpose of computers at work?
 - b. ...in your non-work culture?

Questionnaire: History of Computer Use (Form 01a)

 When do you first remember being introduced to computers? (age and location) (For example, about 10 years old at my friends house, or during my first year of college in the Computer Literacy Class)

age:

location:

condition:

 How did you learn to use a computer? Please mark all the sources that apply. Place a "1" by the most important source of your training, "2" by the next most important source, etc. <u>If you did not learn from a source listed</u>

below, place a "0" by the source)1

Source	Order of importance
self-taught (books, manuals, on-line)	
from friend	
 from family member	(relationship)
in grade school classes	
in high school classes	
 in college classes	
 in a vocational classes	
 in classes offered at work	
 Other	
(Explain:)

3. What kinds of things do you remember learning about using computers?

(For example, how to program in Basic, how to set up equipment, etc.)

¹Upon analysis of this form, it was found that when the participants replied electronically to this form, they only indicated the sources they used. They did not indicate the sources they did not use with "0." Therefore the data analysis is based on frequency of reported sources.

Questionnaire: Hardware and Software Usage (Form 01b)

 What kinds and brands of software where you trained to use during your time in college? (List only the software you remember you learned prior to graduating.)

Software

Used for:

- What kinds and brand of software do you generally use to do your job tasks? (List the software you have learned to use since graduation. If the software is something you have coded, list your name as the brand.)
 Software Used for:
- 3. Are there any kinds of software that you use regularly to perform your job that you think people being trained in your profession should know how to use? Please list:
- 4. What kinds and brands of hardware where you trained to use during your time in college? (List only the hardware you remember you learned to use prior to graduating.)

Hardware Used for:

- 5. What kinds and brands of hardware do you generally use to do your job tasks? (List the hardware you remember you have learned to use since graduation. If you have created the hardware, list your name as the brand.) Hardware Used for:
- What are the various components on this system? (For example, 17" monitor, glidepoint, mouse, etc.) Please list:
- Are there any kinds of technology you use regularly to perform your job that you think other people in your profession should be trained to use? Please list:

- 8. Think back to the kind of information you received during your college training. What are the major differences that stick out in your mind between what you were trained to do and what you need to do in your current job? (For example, you learned to program in Pascal and now only use C++. You were trained to perform simple business logic procedures, but need to program complex algorithms for graphics. Etc.) Please list and explain differences:
- 9. Are there other kinds of training (in areas other than those listed above in software and hardware) you believe people learning about your profession should have? If yes, what? Please list:

Interview: Workstation (Form 02)

- Why do you have your work area arranged this way? Please explain why this setup is best for you.
- 2. Every person has different dimensions. For example you are either taller or shorter than I am. What kinds of things related to your individual physical dimensions effect how you work with computers?

(Go to Job Responsibilities and Tasks, Part 2 and continue interview)

- Do you have a special way you have developed to operate a computer that makes you comfortable when you are working? Describe your method to me.
- 4. What kinds of injury are common to your profession? Have you ever received any information or training on how to set up a computer work station to reduce injury? If so, what do you remember learning?
- 5. If I came to you for advice on setting up my work area to do the same kind of job you do, what would you advise me to do?
- 6. Do you have a regular exercise program? Do you have any specific exercises you do to help prevent computer-related injury? What?
- 7. Have you ever learned any type of exercise for relieving muscle tension while working on a computer or for other purposes related to computer use? What?

Observation of the kinds of motions performed when operating a computer:

Questionnaire: Job Responsibilities and Tasks, Part 1 (Form 02a)

Instructions: On the next page is a listing of your general responsibilities at your current job.

 Rank order these responsibilities in order of what you believe to be importance to accomplishing your job. <u>If you have several task of the same</u> importance, mark them with the same number.)

5 4 3 2 1

Most important

Least Important

 Rank order these responsibilities in order of frequency. Use the rank that comes closest to describing the frequency of the responsibility.

daily = 6

once weekly or a couple of times a week but not daily = 5

about every two weeks = 4

monthly = 3

```
quarterly = 2
```

yearly = 1

 Indicate WHERE you perform this task. List all that apply to each responsibility:

my computer primary workstation = 6

a computer workstation shared with others in my area = 5

not at computer workstation but use physical work area = 4

conference room = 3

away from Company = 2

out of town = 1

Import	Frequency	Location(s)	Responsibility
			(job responsibilities as defined by Company job description for this participant)

Interview: Job Responsibilities and Tasks, Part 2 (Form 02b)

(Compile computer-based responsibilities # from Part 1 form and enter in these

areas):

High frequency (6,5):

Moderate frequency (4,3):

Low frequency (2,1):

Ask interviewee:

- 4. What kinds of things do you generally do in performing these responsibilities?
- 5. Do you have to rearrange your work area in order to do these job responsibilities?
- 6. Do you interact with other people while performing these tasks?
- 7. Estimate how much time you spend on an average day on a computer.

(Go back to Workstation Interview and continue with probe question 3)

Ergonomic Concerns Quiz (Form 02c)

(This form was handed to the participant who was asked to explain what he or she knew about the items shown below.)



VDT Workstation Assessment (Form 02f)

OSHA Draft Document (Occupational Safety and Health Agency 1995) used only for research purposes.

- 1. Can the workstation be adjusted to ensure proper posture by:
- Y N * Adjusting knee and hip angles to achieve comfort and variability?
- Y N * Supporting heels and toes on the floor or a footrest?
- Y N * Placing arms comfortably at the side and hands parallel to the floor (plus or minus 2 inches)?
- Y N * Holding wrists nearly straight and resting them on a padded surface?
 - 2. Does the chair:
- Y N * Adjust easily from the seated position?
- Y N * Have a padded seat pan (soft but compresses about 1 inch)?
- Y N * Have a seat that is approximately 18 inches wide?
- Y N * Have a back rest that provides lumbar support and can be used while working?
- Y N * Have a stable base with casters that are suited to the type of flooring?
- Y N 3. Does the chair manufacturer offer different seat pan lengths (15 to 17 inches) that have a waterfall design?
- Y N 4. Does the seat pan adjust for both height (minimum 4 1/2 inches) and angle (plus or minus 5 degrees)?
- Y N 5. Is there at least 24 inches of clearance for the feet, 15 inches for the knees, and 20 inches of width for the legs and seat relative to the edge of the work surface?
- Y N 6. Is there sufficient space for the thighs between the work surface and the seat?

- Y N 7. Are the keyboard height from the floor and the slope of the keyboard surface adjustable?
- Y N 8. Is the keyboard prevented from slipping when in use?
- Y N 9. Is the keyboard detachable?
- Y N 10. Does the keyboard meet ANSI/HFS 100-1988 (or ISO 9241) standards? (5
 TO 11 DEGREE ANGLE)
- Y N 11. Is the mouse, pointing device, or calculator at the same level as the keyboard?
- Y N 12. Are the head and neck held in a neutral posture?
- Y N 13. Are arm rests provided for intensive or long duration keying jobs?
- Y N 14. Is the screen clean and free from flickering?
- Y N 15. Is the top of the screen slightly below eye level?
- Y N 16. Can the screen swivel horizontally and tilt or elevate vertically?
- Y N 17. Does the monitor have brightness and contrast controls?
- Y N 18. Is the monitor between 18 and 30 inches from the worker?
- Y N 19. Is there sufficient lighting without glare on the screen from lights, windows, and surfaces?
- Y N 20. Are headsets used when frequent telephone work is combined with hand tasks such as typing, use of a calculator, or writing?
- Y N 21. Is the job organized so that workers can change postures frequently?
- Y N 22. Does the worker leave the workstation for at least 10 minutes after every hour of intensive keying and for at least 15 minutes after every 2 hours of intermittent keying?

- 23. Is intensive keying avoided by:
- Y N * Job rotation?
- Y N * Self pacing?
- Y N * Job enlargement?
- Y N * Adequate recovery breaks?
- Y N 24. Is there the possibility of alternating tasks during the shift (e.g., intensive keying or mouse work, filing, copying, telephone calls, intermittent keying)?

25. Are employees trained in:

- Y N * Proper postures?
- Y N * Proper work methods?
- Y N * How to make adjustments to the workstation?
- Y N * Awareness of risk factors for musculoskeletal disorders?
- Y N * How to seek assistance with concerns?
- Y N 26. Are workers able to set their own pace, without electronic monitoring or incentive pay?

If any questions answered no in this section on VDU and keyboard issues, please refer

to Questions 14-19, 25, and 26 in Addendum B-1, Part II OSHA DRAFT.

Interview: Stress Factors (Form 03)

- 1. How has your job changed in the last three years?
- 2. How are task assigned in your work group? Who assigns tasks? How do you know when you have satisfactorily completed an assigned task?
- 3. How are project deadlines determined? Who determines deadlines on projects? What are typical types of deadlines?
- 4. What is stress? How do you define stress? Are there any physical symptoms of stress? Are there any mental symptoms of stress? Are there other things you notice about stress?
- 5. If one of your fellow workers gets really upset at something at work, what usually is the cause of the problem?
- 6. What kinds of things are stressful about your job? How do you commonly deal with this type of stress?
- 7. How do you reduce the amount of stress at work, what would you suggest?
- 8. How does your employer help reduce stress related to your work?
- 9. Why do you think you were chosen to participate in this study?

Appendix E: List of Job Tasks Reported by Participants

APPENDIX E

List Of Job Tasks Reported By Participants

The following job tasks are those tasks found either in the job responsibilities for each type of job or those job responsibilities furnished by participants in addition to the company's job responsibility listing. Where the description of a job responsibility was duplicated because more than one participant had that particular task, there is only one item shown in this list. Therefore, the number of job tasks descriptions here are fewer than the total pool of tasks used for analysis of rankings. The job responsibilities are divided into hardware and software job tasks.

Hardware Job Tasks

- Develops algorithms, determines design methodologies and investigates new technologies within an engineering team.
- As part of a team, assumes design responsibility for ASICs, circuit modules and/or printed circuit assemblies by generating and maintaining written specifications, cost models, schedules and block diagrams.
- Develops high level language functional simulators of ASICs, circuit modules and/or printed circuit assemblies as part of system design investigation and validation.
- Translates high level simulations to detailed schematics or gate level descriptions entered onto an engineering workstation and validates design using various CAE tools.
- Develops physical implementations of designs in conjunction with ASIC designers, printed circuit board layout designers, mechanical packaging designers and prototype fabricators.

- 6. Tests, debugs and otherwise validates prototype versions of the designs.
- Designs, generates, and verifies software test routines and test vectors for the designs to be used for fabrication verification.
- Provides fabrication, manufacturing and test activity support by training and providing technical assistance.
- Ensures the functional, mechanical and electrical compatibility of the product by exchanging pertinent design information and participates in design reviews with engineers developing related assemblies.
- Provides technical assistance to purchasing in specifying new vendors, components and supplies by submitting functional requirements, detailed specifications and/or technical recommendations.
- Develops and monitors work schedules to ensure accomplishment of assigned responsibilities in a timely and efficient manner.
- 12. Product management and development. Keep tract of particular product and its problems, its improvements, support its customers, determine its future and manage its funding. Also manage how product is presented in customer catalogue.
- 13. Product marketing and proposal writing.
- Program requirement definition. Write specifications to define how our products will meet design criteria and trining needs.
- Take customer requirements, and map out a general solution including modeling requirements, real time/IG interface requirements, and IG processing methods.
- 16. Develop algorithms and write code for imbedded microprocessors.

- 17. Assists design engineers in understanding manufacturing costs, capabilities, and constraints so that manufacturability, quality, and cost effectiveness can be included in the design.
- 18. Participates with design engineering, testing engineering, and quality engineering in new product designs to see that assembly, test, and quality requirements are addressed early in the process.
- Researches and recommends new materials, processes, and technologies that can be effectively utilized in new designs.
- Consults with the appropriate manufacturing departments concerning the development and implementation of new tools, technologies, and processes required for new designs.
- Assists in the development of product structures and other engineering documentation necessary for the efficient flow of assemblies in manufacturing.
- 22. Coordinates the building of engineering prototypes, pre-production units, and products that require special manufacturing, and sees that the appropriate documentation is created for manufacturing.
- Consult with manufacturing departments regarding new tools and processes and assist in development and procurement of tools.
- 24. Oversee and train manufacturing people on first build of new assemblies.
- 25. Define and sustain manufacturing's CCA automated assembly capabilities by specifying and justifying the appropriate automated equipment to meet the companies requirements.
- Keep design engineers informed of recent developments in production techniques and advise them on design implications and ease of implementation at company.

- 27. Assists design engineers in understanding manufacturing's capabilities and the impact of design decisions on costs, quality and manufacturability. Work with design engineers in updating manufacturing capabilities to meet state of the are design requirements.
- Become involved early in the design process, participate in design reviews of new products and assemblies and assure the appropriate involvement of other manufacturing organizations (test engineering, QA, purchasing, production, test)
- 29. Assists designers in defining the structure and content of documentation to assure the smooth flow of high quality assemblies through production.
- Participate in make-buy decisions by preparing appropriate technical input, providing vendor capability assessments and cost studies.
- Work with other departments in implementing the tools and processes required by new designs.
- 32. Coordinate the building of prototypes, pre production units and products that require special manufacturing. Create the necessary manufacturing documentation and involve other manufacturing departments as necessary.
- Working from clear and specified objectives, exercising appropriate level of technical skill and judgment, performs VLSI design assignments of high complexity.
- Assumes responsibility for a specific portion of a project and may routinely lead a technical team or serve as a technical liaison.
- 35. Holds and participates in engineering design reviews as appropriate.

- 36. Performs detailed ASIC design engineering on new products as a cooperative portion of a larger project, or independently within project requirements. Activities may include system and chip level design, ASIC implementation and verification, ASIC design characterization and documentation.
- Occasional opportunities to program or debug software tools within designated fields of specialization and assigned areas of responsibilities.
- 38. Consulting on test of ASIC products related to VLSI designs.
- 39. Packaging of ASIC chips.
- 40. ASIC prototype debugging.
- 41. Support manufacturing related to ASIC problems.
- 42. Foundry interface with company to resolve production issues.
- 43. Contribute to VLDI design flow.
- Advise work group on work related problems in design and support of chips production.

Software Job Tasks

- Creates or enhances software programs and tools working from specific and/or detailed specifications and instructions.
- 2. Assists in the test, debug and integration of the develope software.
- Assists in the development of design documentation for use in systems manuals, in-house use documentation, and preparation of technical procedures according to established standards.
- Assists in the maintenance of existing software through enhancement and debug.
- 5. Maintains and enhances knowledge of software development techniques.

- Assists in the creation of database specification documents using, as input, customer specifications and requirements.
- 7. Participates in design and construction of marketing database entities.
- Uses C and other languages to modify utilities that will be used to generate visual databases.
- Learns hardware, real-time, and modeling tools requirements as they relate to visual databases.
- 10. Tunes visual databases for correct color and general appearance.
- Participates in database working groups with customers and in-house management.
- Participates in on-site and in-house visual database integration and final database acceptance procedures.
- Writes technical bulletins and memos detailing procedures of visual database engineering.
- Develops design documentation for use in system manuals and acceptance test procedures.
- Assists in the identification of critical problems in current projects, new proposal requirements, unexplored systems capabilities, etc.
- Develops special and/or unique software tools or packages used in the system development process.
- Works closely with other hardware/software engineers as well as other technical disciplines in defining and establishing the requirements of the various tools, programs, etc.
- 18. Provides on-site engineering support to customers.

- Maintains and enhances current applications as assigned, anticipates needs for information, and creates and/or implements new applications as needed.
- 20. Provides technical support to users. Corrects procedural problems, fixes program errors, and provides training when needed.
- 21. Analyses programs, designs applications, and programs or works with programmers to improve applications as needed.
- 22. Documents procedures for applications and programs.
- 23. Works with department personnel to analyze tasks and procedures, identify department needs, make recommendations, and develop applications to improve procedures and fulfill department needs.
- Keeps up to date on database technology and software development techniques by reading current literature, attending seminars, and using other available sources.
- 25. Meets with members of user community to determine needs. Acts as a liason between various departments to coordinate impact of enhancements and implementations.
- 26. Provides technical leadership for a specific area of specialization.
- 27. Codes, tests, debugs and integrates new software and enhancements to software.
- Develops design documentation for use in system manuals, in-house documentation and the preparation of technical procedures.
- 29. Prepares and conducts preliminary design reviews.
- Assists in the overall design of simulation software to include schedule, resource allocation, top-level design, and configuration management.

- Participate in customer software coordination, on-site integration, and final acceptance.
- 32. Performs formal acceptance tests on software before release.
- Assists in the identification of critical problems in current projects, new proposal requirements, unexplored systems capabilities, etc.
- Develops necessary design documentation as well as miscellaneous user documentation that may be required to support the software.
- Develops special and/or unique software tools or packages used in the system development process.
- 36. Works closely with other hardware/software engineers as well as other technical disciplines in defining and establishing the requirements of the various tools, programs, etc.
- 37. Provides on-site engineering support to customers.

Appendix F:

Tables of Contact with Computers

APPENDIX F

Tables of Contact with Computers

Hardware

Hardware-Related Job Tasks Sorted by Contact with Computer and Frequency of Task

	Participant,	Computer	
Description of job task	task#	contact	Frequency
Develops algorithms, methodologies and investigates new technologies.	11,01	yes	daily
Generating and maintaining written specifications, cost models, schedules and block diagrams.	11,02	yes	daily
Develops physical implementations of designs.	11,05	yes	daily
Product management and development.	11,12	yes	daily
Product marketing and proposal writing.	11,13	yes	daily
Program requirement definition.	11,14	yes	daily
Develop algorithms and write code for imbedded microprocessors.	12,13	yes	daily
Assists in the development of product structures and other engineering documentation.	14,05	yes	daily
Advise work group on work related problems.	15,12	yes	daily
Researches and recommends new materials, processes, and technologies.	13,03	yes	weekly
Assists Designers in defining the structure and content of documentation.	13,13	yes	weekly
Researches and recommends new materials, processes, and technologies.	14,03	yes	weekly
Provides fabrication, manufacturing and test activity support.	11,08	yes	<weekly< td=""></weekly<>
Designs, generates, and verifies software test routines for fabrication verification.	12,07	yes	<weekly< td=""></weekly<>
Provides fabrication, manufacturing and test activity support.	12,08	yes	<weekly< td=""></weekly<>
Develops and monitors work schedules.	12,11	yes	<weekly< td=""></weekly<>
Participates in new product designs.	13,02	yes	<weekly< td=""></weekly<>
Assists in the development of product structures and other engineering documentation.	13,05	yes	<weekly< td=""></weekly<>

Table of Contact with Computers (hardware-	-related jobs) - c	continued.	- ×
	Participant,	Computer	
Description of job task	task#	contact	Frequency
Consult with manufacturing departments regarding new tools and processes and assist in development and procurement of tools.	13,07	yes	<weekly< td=""></weekly<>
Assists Design Engineers in understanding manufacturing costs, capabilities, and constraints.	14,01	yes	<weekly< td=""></weekly<>
Participates in new product designs.	14,02	yes	<weekly< td=""></weekly<>
Coordinates the building of engineering prototypes locates the appropriate documentation for manufacturing.	14,06	yes	<weekly< td=""></weekly<>
Consult with manufacturing departments regarding new tools and processes and assist in development and procurement of tools.	14,07	yes	<weekly< td=""></weekly<>
Define and sustain manufacturing's CCA automated assembly capabilities.	14,09	yes	<weekly< td=""></weekly<>
Keep Design Engineers informed of recent developments in production techniques and design implications.	14,10	yes	<weekly< td=""></weekly<>
Work with Design Engineers in updating manufacturing capabilities.	14,11	yes	<weekly< td=""></weekly<>
Become involved early in the design process and assure the appropriate involvement of other manufacturing organizations	14,12	yes	<weekly< td=""></weekly<>
Assists Designers in defining the structure and content of documentation.	14,13,	yes	<weekly< td=""></weekly<>
Work with other departments in implementing the tools and processes required by new designs.	14,15	yes	<weekly< td=""></weekly<>
Performs VLSI design assignments of high complexity.	15,01	yes	<weekly< td=""></weekly<>
Assumes responsibility for a specific portion of a project and lead a technical team.	15,02	yes	<weekly< td=""></weekly<>
Performs detailed ASIC design engineering on new products.	15,04	yes	<weekly< td=""></weekly<>
Consulting on test of ASIC products related to VLSI designs.	15,06	yes	<weekly< td=""></weekly<>
Support manufacturing related to ASIC problems.	15,09	yes	<weekly< td=""></weekly<>
Foundry interface with company to resolve production issues.	15,10	yes	<weekly< td=""></weekly<>

Table of Contact with Computers (hardware	-related jobs) -	continued.	-
	Participant,	Computer	
Description of job task	task#	contact	Frequency
Keep Design Engineers informed of recent developments in production techniques and design implications.	13,10	no	daily
Participate in make-buy decisions.	13,14	no	daily
Develops high level language functional simulators of ASICs, circuit modules and/or printed circuit assemblies.	11,03	no	weekly
Translates high level simulations to detailed schematics.	11,04	no	weekly
Designs, generates, and verifies software test routines for fabrication verification.	11,07	no	weekly
Ensures the functional, mechanical and electrical compatibility of the product.	11,09	no	weekly
Provides technical assistance in specifying new vendors, components and supplies.	11,10	no	weekly
Develops high level language functional simulators of ASICs, circuit modules and/or printed circuit assemblies.	11,11	no	weekly
Assists Design Engineers in understanding manufacturing costs, capabilities, and constraints.	13,01	no	weekly
Participate in make-buy decisions.	14,14	no	weekly
Tests, debugs and validates prototype versions of the designs.	11,06	no	<weekly< td=""></weekly<>
Develops algorithms, methodologies and investigates new technologies.	12,01	no	<weekly< td=""></weekly<>
Generating and maintaining written specifications, cost models, schedules and block diagrams.	12,02	no	<weekly< td=""></weekly<>
Develops high level language functional simulators of ASICs, circuit modules and/or printed circuit assemblies.	12,03	no	<weekly< td=""></weekly<>
Translates high level simulations to detailed schematics.	12,04	no	<weekly< td=""></weekly<>
Develops physical implementations of designs.	12,05	no	<weekly< td=""></weekly<>
Tests, debugs and validates prototype versions of the designs.	12,06	no	<weekly< td=""></weekly<>
Ensures the functional, mechanical and electrical compatibility of the product.	12,09	no	<weekly< td=""></weekly<>
Provides technical assistance in specifying new vendors, components and supplies.	12,10	no	<weekly< td=""></weekly<>

	Participant,	Computer	-
Description of job task	task#	contact	Frequency
Take customer requirements, and map out a general solution.	12,12	no	<weekly< td=""></weekly<>
Coordinates the building of engineering prototypes locates the appropriate documentation for manufacturing.	13,06	no	<weekly< td=""></weekly<>
Oversee and train manufacturing people on first build of new assemblies.	13,08	no	<weekly< td=""></weekly<>
Define and sustain manufacturing's CCA automated assembly capabilities.	13,09	no	<weekly< td=""></weekly<>
Work with Design Engineers in updating manufacturing capabilities.	13,11	no	<weekly< td=""></weekly<>
Become involved early in the design process and assure the appropriate involvement of other manufacturing organizations	13,12	no	<weekly< td=""></weekly<>
Work with other departments in implementing the tools and processes required by new designs.	13,15	no	<weekly< td=""></weekly<>
Coordinate the building of prototypes and create the necessary manufacturing documentation.	13,16	no	<weekly< td=""></weekly<>
Consults concerning the development and implementation of new tools, technologies, and processes required for new designs.	14,04	no	<weekly< td=""></weekly<>
Oversee and train manufacturing people on first build of new assemblies.	14,08	no	<weekly< td=""></weekly<>
Coordinate the building of prototypes and create the necessary manufacturing documentation.	14,16	no	<weekly< td=""></weekly<>
Holds and participates in engineering design reviews as appropriate.	15,03	no	<weekly< td=""></weekly<>
Program or debug software tools within designated fields of specialization and assigned areas of responsibilities.	15,05	no	<weekly< td=""></weekly<>
Advise in Packaging of ASIC chips.	15,07	no	<weekly< td=""></weekly<>
ASIC prototype debugging.	15,08	no	<weekly< td=""></weekly<>
Contribute to VLDI design flow.	15,11	no	<weekly< td=""></weekly<>
Total Tasks	71		

Table of Contact with Computers (hardware-related jobs) - continued.

Software

Software-Related Job Tasks Sorted by Contact with Computer and Frequency of Task

	Participant,	Computer		
Description of job task	task#	contact	Frequency	
Creates or enhances software programs and tools working from specific and/or detailed specifications and instructions.	21,01	yes	daily	
Assists in the maintenance of existing software through enhancement and debug.	21,04	yes	daily	
Participates in design and construction of marketing database entities.	22,02	yes	daily	
Keeps up to date on database technology and software development techniques.	23,06	yes	daily	
Codes, tests, debugs and integrates new software and enhancements to software.	24,02	yes	daily	
Codes, tests, debugs and integrates new software and enhancements to software.	25,02	yes	daily	
Develops design documentation for use in system manuals, in-house documentation and the preparation of technical procedures.	25,03	yes	daily	
Assists in the identification of critical problems in current projects, new proposal requirements, unexplored systems capabilities, etc.	25,08	yes	daily	
Develops necessary design documentation as well as miscellaneous user documentation that may be required to support the software	25,09	yes	daily	
Develops special and/or unique software tools or packages.	25,10	yes	daily	
Defining and establishing the requirements of the various tools, programs, etc.	25,11	yes	daily	
Development of design documentation for use in systems manuals, in-house use documentation, and preparation of technical procedures according to established standards.	21,03	yes	weekly	
Assists in the identification of critical problems.	22,10	yes	weekly	
Maintains and enhances current applications and creates and/or implements new applications.	23,01	yes	weekly	
Analyses programs, designs applications, and programs.	23,03	yes	weekly	
Analyze tasks and procedures, identify department needs, make recommendations, and develop applications.	23,05	yes	weekly	

Table of Contact with Computers (software-	Participant.	Computer	
Description of job task	task#	contact	Frequency
Provides technical leadership for a specific area of specialization.	24,01	yes	weekly
Prepares and conducts preliminary design reviews.	25,04	yes	weekly
Assists in the test, debug and integration of the developed software.	21,02	yes	<weekly< td=""></weekly<>
Maintains and enhances knowledge of software development techniques.	21,05	yes	<weekly< td=""></weekly<>
Assists in the creation of database specification documents.	22,01	yes	<weekly< td=""></weekly<>
Uses C and other languages to modify utilities	22,03	yes	<weekly< td=""></weekly<>
Learns hardware, real-time, and modeling tools requirements as they relate to visual databases.	22,04	yes	<weekly< td=""></weekly<>
Tunes visual databases for correct color and general appearance.	22,05	yes	<weekly< td=""></weekly<>
Participates in on-site and in-house visual database integration and final database acceptance procedures.	22,07	yes	<weekly< td=""></weekly<>
Writes technical bulletins and memos detailing procedures of visual database engineering.	22,08	yes	<weekly< td=""></weekly<>
Develops design documentation for use in system manuals and acceptance test procedures.	22,09	yes	<weekly< td=""></weekly<>
Develops special and/or unique software tools.	22,11	yes	<weekly< td=""></weekly<>
Works closely with other hardware/software engineers in defining and establishing the requirements of the various tools, programs, etc.	22,12	yes	<weekly< td=""></weekly<>
Provides technical support to users.	23,02	yes	<weekly< td=""></weekly<>
Meets with members of user community to determine needs.	23,07	yes	<weekly< td=""></weekly<>
Develops design documentation for use in system manuals, in-house documentation and the preparation of technical procedures.	24,03	yes	<weekly< td=""></weekly<>
Prepares and conducts preliminary design reviews.	24,04	yes	<weekly< td=""></weekly<>
Participate in customer software coordination, on-site integration, and final acceptance.	24,06	yes	<weekly< td=""></weekly<>

Table of Contact with Computers	(software-related	iobs)) -	continued
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	Participant,	Computer	
Description of job task	task#	contact	Frequency
Performs formal acceptance tests on software before release.	24,07	yes	<weekly< td=""></weekly<>
Develops necessary design documentation as well as miscellaneous user documentation that may be required to support the software.	24,09	yes	<weekly< td=""></weekly<>
Develops special and/or unique software tools or packages.	24,10	yes	<weekly< td=""></weekly<>
Defining and establishing the requirements of the various tools, programs, etc.	24,11	yes	<weekly< td=""></weekly<>
Provides technical leadership for a specific area of specialization.	25,01	yes	<weekly< td=""></weekly<>
Assists in the overall design of simulation software to include schedule, resource allocation, top-level design, and configuration management.	25,05	yes	<weekly< td=""></weekly<>
Participate in customer software coordination, on-site integration, and final acceptance.	25,06	yes	<weekly< td=""></weekly<>
Performs formal acceptance tests on software before release.	25,07	yes	<weekly< td=""></weekly<>
Provides on-site engineering support to customers.	25,12	yes	<weekly< td=""></weekly<>
Assists in the identification of critical problems in current projects.	24,08	no	weekly
Participates in database working groups with customers and in-house management.	22,06	no	<weekly< td=""></weekly<>
Provides on-site engineering support to customers.	22,13	no	<weekly< td=""></weekly<>
Documents procedures for applications and programs.	23,04	no	<weekly< td=""></weekly<>
Assists in the overall design of simulation software to include schedule, resource allocation, top-level design, and configuration management.	24,05	no	<weekly< td=""></weekly<>
Provides on-site engineering support to customers.	24,12	no	<weekly< td=""></weekly<>
Total tasks	49		

Appendix G: Table of Job Task Rankings Sorted by Frequency

APPENDIX G

Hardware Total = 71				Software Total = 49			
Job Task	Frequency	Location	Import	Job Task	Frequency	Location	Import
11,01	6	6	5	21,01	6	6	1
11,02	6	6	5	21,04	6	6	1
11,05	6	6	5	22,02	6	6	5
11,12	6	6	5	23,06	6	6	5
11,14	6	6	5	24,02	6	6	5
12,13	6	6	4	25,02	6	6	5
13,04	6	4	5	25,03	6	6	5
13,09	6	4	5	25,08	6	6	4
14,05	6	6	4	25,09	6	6	4
15.12	6	6	4	25.10	6	6	4
13.03	5	6	5	25.11	6	6	5
13.07	5	4	5	21.03	5	6	2
13.10	5	6	5	22.05	5	5	5
13.14	5	6	4	22.10	5	6	5
14.01	5	3	4	22.12	5	4	5
14.02	5	4	5	23.01	5	6	5
14.06	5	4	5	23.03	5	6	5
14.12	5	3	5	23.05	5	6	5
14.13.	5	4	4	24.01	5	6	4
14,16	5	4	5	21.02	4	6	1
15,10	5	3	3	22,01	4	6	5
11,03	4	6	5	22.03	4	6	4
11,04	4	6	5	22,04	4	6	5
11,06	4	4	5	23,02	4	6	5
11,07	4	6	3	23,07	4	6	4
11,11	4	6	4	24,08	4	6	4
13,02	4	3	4	25,04	4	6	5
13,06	4	4	4	21,05	3	6	3
13,13	4	6	2	22,06	3	3	4
13,15	4	4	5	22,07	3	5	3
13,16	4	4	4	22,09	3	6	2
14,03	4	6	3	24,03	3	6	3
14.04	4	4	5	24.04	3	3	4
14,07	4	4	3	24,09	3	6	3
14,10	4	3	4	24,10	3	6	3
14.11	4	3	4	24.11	3	6	3
14.15	4	3	3	25.01	3	6	2
11.08	3	4	2	25.05	3	6	5
11.09	3	6	4	22.08	2	6	4
11.10	3	6	2	22,11	2	6	4
11.13	3	6	3	23.04	2	6	4

Table of Job Task Rankings Sorted by Frequency^{1,2}

¹Refer to Appendix E for a listing of job tasks with associated descriptions. ²Ranking criteria provided at end of Appendix E-2.

Job Task	Frequency	Location	Import	Job Task	Frequency	Location	Import
12.11	3	4	3	24,05	2	4	4
13.01	3	6	3	24.07	2	6	4
13,11	3	3	3	25.06	2	3	3
14,08	3	3	4	25,07	2	6	4
14,14	3	6	2	25,12	2	5	3
15,06	3	3	2	22,13	1	1	3
15,07	3	5	3	24,06	1	6	4
12,01	2	4	2	24,12	1	2	4
12,09	2	3	2				
12,12	2	4	4				
13,05	2	6	2				
13,08	2	4	3				
13,12	2	3	1				
14,09	2	6	4				
15,03	2	5	4				
15,09	2	4	4				
12,02	1	6	2				
12,03	1	6	2				
12,04	1	6	2				
12,05	1	5	2				
12,00	1	4	2				
12,07	1	3	1				
12,00	1	4	1				
15.01	î	6	5				
15.02	ĩ	6	5				
15.04	1	6	4				
15,08	1	4	4				
15,11	1	3	4				
15,05	0.5	6	1				
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requency.	o dally, .	J less that	i dany or	weekiy, 4 Diwe	ckiy, 5 m	Jinny, 2	quarterry
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ocation:	6 assigne	ed workst	ation; 5 s	hared workstati	on; 4 gene	eral work	area;
	3 confere	ence roon	n; 2 off-si	te; 1 client locat	ion		
mportance: Range from 5 (most important) to 1 (least important)							

Table of Job Task Rankings (continued)

Appendix H:

Correct Responses to Ergonomic

Concerns Quiz

APPENDIX H

Correct Responses to Ergonomic Concerns Quiz

- 1. Viewing distance: generally 18" to 30" or whatever range reduces eye fatigue.
- Reach area: The immediate area where work related objects are placed, generally 24" to 28". The reach area should be comfortable and not require muscle strain to retrieve objects.
- 3. Head posture: Upright and relaxed. Head should not be excessively forward bending and chin should not be continuously tilted upward causing the head to tilt back. A preferred eye angle of between 0° and 30° downward to a maximum of 45° downward is correct (see 14, line of sight).
- Shoulder posture: Keep back in an upright position with shoulders not rounded—do not slouch. Back should also be without tilt in the pelvic area.
- 5. Arm posture: Arms should be held loosely at the sides of the torso with the elbows by the trunk of the body forming a 90° angle with the upper arm. Any position where the arm is unsupported while extended for long periods of time will cause muscle fatigue. Also, the wrists should be as straight as possible when the fingers are placed on the keyboard or on a mouse input device.
- 6. Back support: The primary support for the back comes from the back muscles. The back should be kept in an comfortable, upright position with the pelvic area perpendicular, not tilted to the chair seat. Sufficient lumbar support can be placed in the lumbar area of the back ("small of the back") to help facilitate supportive posture especially during periods of extended keyboarding or workstation time. Three possible postures are open (150° at hip joint; used for extended periods of data entry); upright (90° at hip joint;

used for data entry mixed with other types of motions); or closed (less than 90° at hip joint; used for reading or drawing postures).

7. Chair adjustability: The chair should be adjusted first to the height of the person using the chair. The minimal height of the seat of the chair from the floor should be no less than the length of the leg from the foot heel (flat on the floor) to the lower back of the knee. (Back up to the chair seat and check where the seat touches the back of your knees.) If the work area requires the chair seat to be adjusted heigher to optimise work actions, add a foot rest. Adjust the chair back support to fit the lower back as well as provide adequate support to the middle back. If no lumbar support is available in the chair, get a round pillow to place in the lumbar area. The arm rests should allow the elbows/forearms to rest comfortably and provide a straight approach of the forearm and wrist toward the keyboard while keying (see Fig F.1)



Figure F.1. Example of footrest

8. Foot position: Feet should either be flat on the floor or resting on a slanting foot rest that allows the lower legs to be at a comfortable angle in front of the work area. A foot rest is often necessary for people who need to adjust their chair height to meet table height rather than the length of their lower leg. Also, there should be adequate clearance between the top of the leg and the work surface to allow comfortable leg movement as well as adequate area beneath the work surface to allow the legs and feet to move without bumping into objects.
- 9. Legs: The underside of the leg should not be pressed against the edge of the chair seat. Legs should extend beyond the edge of the chair seat. The pan of chair seat should be adjusted to allow the lower side of the leg to be comfortable.
- Angle (elbow): A 90° angle between the upper arm and the lower forearm with the elbows at the side of the body.
- 11. Keyboard: A maximum 15° upward slant to a maximum -5° downward slant. Keys should be comfortably spaced for the size of your fingers. A QWERTY type keyboard is the industry standard. The input area should be adjusted to an adequate height for the keyboard or other input devices to be level with the arms in a 90° angle to torso.
- 12. Work surface area: The work surface area should be sufficiently high to provide proper adjustment of the monitor height for your needs. There should be sufficient room at the sides of the work area to place all items necessary for the current task. If a document holder is needed, it may be placed on the most comfortable viewing side within an appropriate viewing distance to prevent eye strain. Documents may be placed on the table between the keyboard and monitor as long as the document is within the eyes field of view and does not require the head to be continuously tilted forward.
- 13. Field of view: The working area of view generally ranges from looking straight ahead to an upward or downward angle that is possible by moving the eyes without tilting the head. The field of view should not consistently require movement of the head.
- 14. Line of sight: The line of sight is straight ahead to a downward angle of 0° to 30°. Also, if bifocals are worn, the monitor should be lowered so the most common area of viewing is sufficiently low to keep the head from tilting

backward when viewed through bifocals. Alternative eyeglass for use only with a monitor help correct head angle for line of sight.

CURRICULUM VITAE

Vicki S. Napper (October 1997)

CAREER OBJECTIVE:

To obtain a position in a research-based environment that is focused on the appropriate applications of technology. Special areas of interest: human-computer interface, workstation design, and application of instructional methods.

EDUCATION:

BA in English with a Photography minor, Weber State College, Ogden, Utah. (6/82) GPA: 3.5 Emphasis in writing, Honors Curriculum, Departmental Honors. MS in Instructional Technology, Utah State University, Logan, Utah (9/90). GPA 3.84, Emphasis in computer-based instruction. Ph.D. in Instructional Technology, Utah State University, Logan, Utah (expected 12/97). Grad GPA 3.77. Dissertation research in the area of the job task model as a basis for computer usage a work place setting.

EXPERIENCE:

INSTRUCTOR

Weber State University, Education Department (1997). Instructional technology course for student educators.

Utah State University, Department of Instructional Technology (1990).

Instructional technology and computer literacy for students/educators.

KEYNOTE SPEAKER. 1997 Association for Educational Communication and Technology National Convention. Session: Can you improve your EQ (ergonomicquotient)? NATIONAL COCHRAN INTERN, 1996 Association for Educational Communication and Technology.

GRADUATE ASSISTANT, Utah State University, Center for Persons with Disabilities, Technology Division. (1/90 to 10/91; 1/95 to 5/96).

Instructional designer for parent training in *Reading for All Learners* reading program.

<u>Evaluation specialist</u> for focus group evaluations to provide information on paraprofessional training in the State of Utah.

Instructional designer for teacher training manual for *Cooperative Interaction Social* Skills Videodisc Program.

RESEARCH ANALYST, Southwest Research Institute (10/91-12/94), Hill AFB Branch.

Data analysis and design of training materials for LM Directorate training at Hill AFB (videotape, videodisc, and CBT course materials).

Research assistant assigned to R&D contract for Wright-Patterson AFB.

INSTRUCTIONAL DESIGNER

<u>Utah State Board of Education</u> (1991). *Introduction to Computer Literacy Course* for Weber-Ogden Applied Technology Center.

NSF Grant to Logan City Schools (1989). HyperCard Science Stacks, resources for difficult to teach topics

MANAGER/PRODUCTION ASSISTANT, Weber State College (12/80 to 8/88). Managed WILKIT Teacher Education Program and oversaw production of educational modules.

INSTRUCTIONAL PRODUCT DEVELOPMENT HISTORY

Computer-Based Training Materials

Parent Training/Audio Sounds (1996)

Intelligent Authoring System (1993)

Safety Training Materials for AAC (1992-1993)

NSF Science Project HyperCard Stacks (1989)

Videodisc Programs and Associated Materials:

Computer Numerical Control (1992)

Videodisc version of existing videotaped safety training materials (1991-1992)

Teacher Training for use with *Cooperative Interaction Social Skills* videodisc program (1990-1991)

Videotape Programs

Parent Training/Lesson Example to Teach Reading (1996)

Propellant Handling Safety Training (1992)

Computer Numerical Control: Coordinates & Computing (1992)

A Short History of Karate (1989)

Evaluation

Policy Analysis of Computer Services at Utah State University (1995)

Pilot Study of Student Usage of Computing Systems (1995)

Summative Evaluation of MadMath Videotape Program (1994)

Feasibility Study for Repurposing Existing Training Materials (1992)

Focus Groups of Special Education Teacher Training Paraprofessionals (1992)

Formative Evaluation Report to the Logan City School District on Implementation

of the Educational Technology Initiative. (1990-1991 School Year)

Text-Based Instructional Materials

Taxonomy for interaction questions, K-3 level, Reading of All Learners program Introduction to Computer Literacy Training Materials(1991) WILKIT Teacher Education Modules, Editor (1984-1988)

PUBLICATIONS, REPORTS, AND PRESENTATIONS

Scholarly Publications

- Assisted with chapter, *Audio tools for distance education* in Distance Education Strategies and Tools. (1994).
- [Review of the book *Design at Work*.]. Educational Technology Research and Development, 42: 1, 97-99.
- [Review of the book Alternatives to Universities]. Educational Technology Research and Development, 40:2, 118-119.

Reports

- Focus Group Analysis. Report to Director of Technology, Center for Persons with Disabilities. 1992.
- Final Report on Telephone Survey of Users of Mad Math Video Product. Report to Developers. 1992.
- Feasibility Study of Repurposing Videotapes to Videodiscs. Report to Training Division, Hill AFB, Utah.
- Educational Technologies Initiative. Joint Report on Formative Evaluation of Technology Implementation in Logan City School District. 1991

Presentations

Can you Improve Your EQ? Designing Workstations. Keynote Address at the National Association for Educational Computing and Technology Conference, Albuquerque NM, 1997.

- The Adult Learner and Computers. Session, national convention, AECT, Indianapolis, IN, 1996.
- What is Your Ergo-IQ? A workshop to teach ergonomic awareness in design of instruction and computer work area. Utah State University, 1994
- Creation of Electronic Storyboards using Toolbook Authoring System. Session at national convention, AECT, Nashville, TN, 1994.
- Use of Focus Groups in Educational Research. Session at national convention, AECT, Nashville, TN, 1994.
- Integration of Computers into the Learning Environment. The Utah Council for Computers in Education, 1990 Spring Convention, Joint Presentation

PROFESSIONAL ORGANIZATIONS

Association for Educational Communications and Technology (AECT). Member since 1989. National ECT Cochran Intern in 1996. Positions currently held: member of Professional Ethics Committee; Director-at-Large of Industrial Training and Education Division (ITED).

Human Factors Society. Member 1993-1997.

HONORS

National Intern (AECT), Cochran Intern, Indianapolis, IN. (1996).

Departmental Honors, B. A., English Department, Weber State College (1982).