Software Design: Communication Between Human Factors Engineers and Software Developers

by

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(ABSTRACT)

As computers pervade aspects of daily life, users demand software that is easy to use. It has been suggested that adding human factors engineers (HFEs) to software development teams would help software development companies meet these user demands. However, there are qualitative data which suggest that software developers (SDs) and HFEs do not communicate well with each other. It is believed that this lack of communication has inhibited the use of HFEs on software development teams. It is further believed that this lack of communication is due in part to the differences in the frames of reference of HFEs and SDs.

Thus, the objectives of this thesis are:

1. To develop an instrument which can be used to determine the differences in the frames of reference of HFEs and SDs.
2. To test the instrument.

Three questionnaires were developed to probe the differences in the frames of reference of HFEs and SDs. The first, a background questionnaire, probed for information concerning software development experience and knowledge of specific software industry terms. The second was a software development activities questionnaire which was used to ascertain the

importance of participation of certain professionals in software development activities. Finally, the usability information questionnaire was used to determine what type of supporting information would be necessary for a design change at certain points in the development of the product.

Participants (30 HFEs and 30 SDs) completed the questionnaires. It was found that HFEs and SDs do differ in their frames of reference. It was also found that some of these differences could cause a lack of communication between HFEs and SDs. It is suggested that software companies provide interdisciplinary training for their employees to help reduce these differences and to improve communication.

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INTRODUCTION

In today's world nearly everyone comes into contact with computers. This contact may be as innocuous as getting money from an automated teller or as involved as programming a computer for a certain function. As computers pervade aspects of their business and personal life, users demand software that works as advertised and that requires little or no training. Not only are casual users demanding high quality software, but business management is too. Management has grown tired of the days when the installation of a new software application meant hours of training for employees and the addition of support staff to maintain the software.

Software companies trying to meet these user demands have emphasized the development of easy-to-use software. Software development teams are asked to determine what constitutes a usable product and then to build it. Unfortunately, many software development teams do not have personnel with expertise to meet this product objective.

Most software developers are trained in computer science; thus, few have knowledge of how to build software that is easy to use (Branscomb and Thomas, 1984; Carroll and Campbell, 1986; Newell and Card, 1986). On the other hand, human factors engineers are trained in the development of easy-to-use products. Several experts (Card, Moran, and Newell, 1983; Gould, 1988; Mantei and Teorey, 1988; Rubinstein and Hersh, 1984;) agree that human factors engineers aid development teams in the creation of easy-to-use products. However, the addition of human factors engineers to software development teams has not yet become commonplace.

According to several studies (Grudin and Poltrock, 1989; Hammond, Jorgensen, MacLean, Barnard, and Long, 1983; Meister, 1987; Perrow, 1983), lack of communication between software developers (SDs) and human factors engineers (HFEs) is a contributing factor to the lack of HFEs on software development teams. It is believed that part of this lack of communication is due to the differences in emphasis that HFEs and SDs place on certain aspects of the software development process. To determine where these differences lie, two areas of software development were explored: software development activities and usability information. Using a questionnaire, HFEs and SDs were asked to indicate how important it is for certain members of a software development team to participate in software development activities. In addition, SDs and HFEs were asked to indicate whether a product should be changed at certain points in the development process based upon the type of usability information used to support the change request. By examining the differences in emphasis that SDs and HFEs place in these areas, insight was gained into the cause for their lack of communication.

BACKGROUND

Software developers (SDs)

From many studies that have been conducted on SDs (Tables 1 and 2), a composite set of descriptive characteristics can be developed. A typical SD is male, less than 50 years of age, and possesses an undergraduate degree in mathematics, computer science, or electrical engineering. He is unlikely to pursue a graduate degree, but if he does it will probably be in computer science. He is goal oriented and satisfied with the line of work he has chosen. Even though the work environment is informal, there are regular deadlines and he is required occasionally to work overtime. He is a self-motivating individual who requires little supervision. He does not require as much social interaction as other types of workers, but he must be able to communicate with team members. His work requires him to possess many different types of skills, including the ability to make trade-offs among requirements, insuring that the most important requirements are satisfied first. Even though he can make the trade-offs on the requirements, he usually lacks the skills to communicate these requirements to the lay person. His salary is among the highest in the scientific work force with an approximate average annual income of $40,000. If he aspires to management, it is more than likely that his first promotion will be to project manager.

Table 1. Software Developer Characteristics

Characteristic	*Reference*
Salaries among highest in scientific work force 88% white 71% male 80% less than 50 years of age 78% work in industry 5% pursue graduate study	U.S. National Science Foundation (1988)
$37,300 average annual salary	U.S. National Science Foundation (1986)
89% college graduate Satisfied with the job Regular deadlines - intense work environment Sometimes required to work overtime	Norback (1987)
Sense of purpose; goal-oriented Satisfies important requirements first Makes trade-offs among requirements Communicates to team members	Marca (1984)
Needs personal growth and development Needs social interaction less than people in other fields Needs several types of skills	Curtis (1984)
Usually liberal Lacks ability to communicate with the lay person	Harold (1988)

Table 2. Software Developer's Areas of Study

Adapted from Norback (1987)

Area of Study	*College Major (%)* *n=260*	*Graduate Study (%)* *n=181*
Mathematics	30	22
Computer Science	15	23
Electrical Engineering	15	12
Business/Management	11	17
Other Sciences	13	10
Other Engineering	5	8
Arts and Humanities	7	4
Social Sciences	4	--
Other	1	3

Human Factors Engineers (HFEs)

> Human factors discovers and applies information about human behavior, abilities, limitations, and other characteristics to the design of tools, machines, systems, tasks, jobs, and environments for productive, safe, comfortable, and effective human use.
>
> Sanders and McCormick (1987, p. 5)

In the realm of software development, this definition implies that an HFE is responsible for many activities which include:

- Researching human behaviors with different user interfaces.
- Applying research data to the design of software applications.
- Determining what tasks should be software aided.
- Determining how software will impact human performance.

These activities require an individual who is trained in human information processing, system design and development, system training, performance aides and documentation, and conducting usability tests (Bailey, 1989). To meet these requirements an HFE is trained in multidisciplinary fields, including psychology, biology, biomechanics, engineering, statistics, and systems design.

HFEs have not been the subject of close scrutinization as have been SDs. Most of the information available on HFEs is from the Human Factors Society (HFS) (1990) (Table 3). From this information it can be ascertained that an HFE typically has an advanced degree. Psychology accounts for 50% of the highest degrees earned by HFS members. By examining just the HFS members with master's degrees, 40% of them have their master's degree in psychology, 2% have their master's degrees in computer science (Table 4).

In addition, the members of HFS specialize in many different fields, from aeronautics to workload measurement. Software development and design is

Table 3. Educational Background (Highest Degree Held) of HFS Membership Adapted from Human Factors Society (1990)

Acedemic/Specialty	*Bachelor*	*Master*	*Doctor*	*Total*
Psychology	7.7%	14.2%	28.1%	50.0%
Industrial Engineering	1.6%	5.9%	3.8%	11.3%
Other Engineering	3.5%	2.8%	2.0%	8.3%
Human Factors/Ergonomics	1.7%	4.0%	2.1%	7.8%
Medicine/Physiology/Life Science	0.8%	1.4%	2.4%	4.6%
Business Administration	0.7%	2.4%	0.1%	3.2%
Industrial Design	2.1%	0.9%	0.1%	3.1%
Education	0.2%	0.8%	1.2%	2.2%
Computer Science	0.3%	0.6%	0.6%	1.5%
Other	3.0%	2.6%	2.4%	8.0%
Total	35.6%	42.8%	21.6%	100.0%

Table 4. Educational Background of HFS Members with Master's Degrees Adapted from Human Factors Society (1990)

Acedemic/Specialty	*Percentage*
Psychology	40%
Industrial Engineering	17%
Human Factors/Erogonomics	11%
Other Engineering	8%
Business Administration	7%
Medicine/Physiology/Life Science	4%
Industrial Design	2%
Education	2%
Computer Science	2%
Other	7%

not an identifier in the Directory, so it is impossible to determine from the HFS Directory how many HFS members perform this type of work. However, Table 5 shows that the number of HFS members working for computer companies has nearly quadrupled over the last 15 years.

Communications Between SDs and HFEs

It is believed that one of the reasons HFEs have not been incorporated into software development environments is the lack of understanding by SDs of the value that an HFE can add to the development effort. Part of this lack of understanding can be attributed to a lack of communication (Mantei and Teorey, 1988; Meister, 1987). Mantei and Teorey (1988) indicated that a lack of communication exists between SDs and HFEs because of their differences in training.

Schramm developed a communication model (Figure 1) which illustrates the lack of communication between individuals with different frames of reference (Hunt, 1980). In Schramm's model, this frame of reference is based upon environment, education, native abilities, and current situation. The more similarities there are in two persons' frames of reference, the more likely it is that the person who sends the message will be understood by the person who receives the message. As seen in Figure 1a, the message is encapsulated by both frames of reference; thus, none of the message is lost. However, most of the message lies outside the receivers' frame of reference and that part of the message is not understood by the receiver (Figure 1b).

Because of the typical backgrounds of SDs (mathematics, computer science, electrical engineering) and HFEs (psychology, industrial engineering),

Table 5. Number of HFS Members Employed by Computer Companies

Adapted from Grimes, Ehrlich, and Vaske (1986)

Company	*1975*	*1980*	*1985*	*1990*
Apple	0	0	1	4
Bell/AT&T/Western Electric	50	82	183	165
Burroughs	4	1	7	0
Control Data	0	5	3	1
DEC	0	3	16	18
Hewlett-Packard	0	0	7	27
Harris	0	7	20	20
Honeywell	19	33	35	16
IBM	32	41	139	172
NCR	6	9	6	4
Prime	0	0	2	0
Sperry	3	7	13	0
Tektronix	0	8	6	4
Wang	0	0	10	6
Xerox	8	20	35	37
Total	122	216	483	474

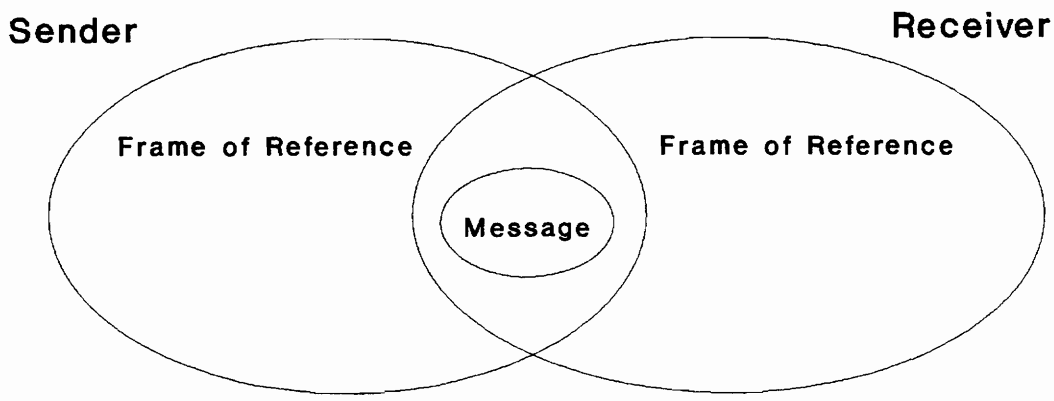

Figure 1a. None of the signal is lost.

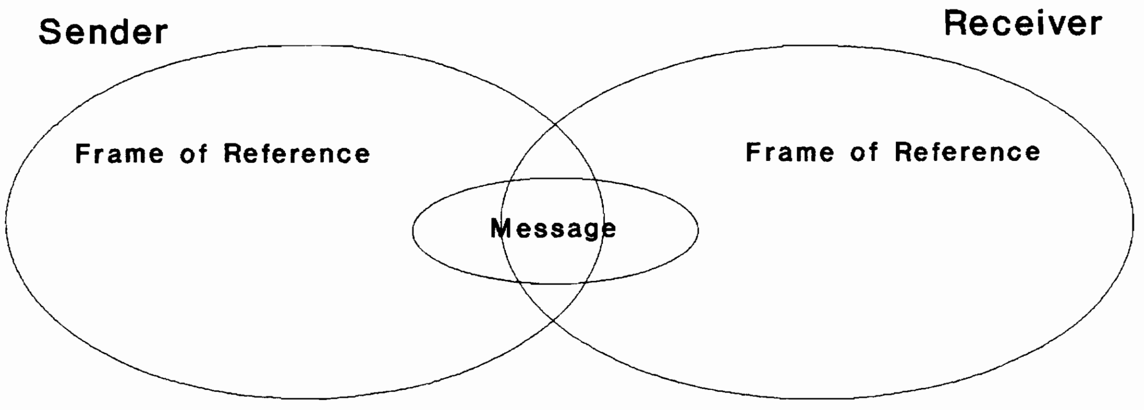

Figure 1b. Most of the signal is lost.

Figure 1. Illustration of Schramm's communication model. Adopted from Hunt (1980).

it is appropriate to assume that their frames of reference are dissimilar. Thus, for these two groups to communicate effectively, each group must expand its frame of reference (Hunt, 1980; Mantei and Teorey, 1988; Scott, 1984). By expanding their frames of reference, more of each message will be communicated and therefore, SDs and HFEs will better understand each other. Better communication will enable them to design and build easy-to-use products more efficiently.

Related Research

Meister (1987). Over 20 years ago, Meister and Farr (1967) identified a lack of communication between HFEs and system designers. Many studies have been conducted since then and Meister (1987) did a good job of summarizing them. The system designers and engineers referred to by Meister incorporate many different types of development environments. However, from field observations, Meister's comments can be applied to software development environments and, in particular, SDs.

The results of these studies that are pertinent to this thesis are:

- SDs do not do specific, systematic design analysis.
- SDs rely on past design decisions.
- SDs prefer to design with a minimum of input from others.
- SDs rarely modify their designs, except in minor details.
- SDs prefer data phrased in quantitative, graphic, or tabular terms.

Meister also states that more research needs to be done in this area. Most of the studies he cites are from the 1960s and 1970s.

Perrow (1983). Perrow (1983) examined the lack of communication between HFEs and system designers from an organizational analyst's perspective. Even though he used examples from the design of military equipment, his statements also apply to high-technology products (e.g., software) and, therefore, to SDs. Perrow believed that for HFEs to have more value in industrial organizations, top management must recognize the value of HFEs and put a structure in place to recognize their efforts. He believed that most SDs and management are unaware of the consequences of shortcomings in software design. HFEs must communicate shortcomings in designs in a manner that SDs can understand.

Perrow indicates that SDs, beginning with college, are trained to focus on the internal design of the system, not on the external design or user interface. Also, because HFEs argue for the benefits of the users who may be seen as error-prone by the SDs and top management, the HFEs may be viewed as error-prone themselves and their information discounted.

Hammond et al. (1983). Many of Perrow's statements were reinforced by a study conducted by Hammond, Jorgensen, MacLean, Bernard, and Long (1983). Hammond et al. interviewed five SDs. These SDs stated that very little consideration was given to the users and the tasks that they perform. The SDs indicated that internal design and consistency take precedence over the external design and user interface. When queried about HFEs, SDs had the following commentaries:

- HFEs are only valuable for help panels.
- HFE input is too narrow in scope.
- HFE research does not play a role in design efforts.

Grudin and Poltrock (1989). Grudin and Poltrock (1989) conducted the first study involving more than one discipline in the software development arena. Grudin and Poltrock sent questionnaires to seven large companies where over 200 participants from multiple sites completed them. The participants designers consisted of HFEs, SDs, marketing specialists, industrial designers, training developers, and technical writers. The following summarizes the results that are pertinent to this thesis:

- SDs felt that they were involved in projects at just the right time, while HFEs, marketing specialists, technical writers, and training developers felt that they were involved too late.
- SDs reported having issues arise with which they would like help from HFEs. Yet, when HFE help was available SDs reported that the help obtained was only moderately useful.

In conclusion, Grudin and Poltrock indicated that software development is a multidisciplinary activity that requires coordination and communication. Because of the nature of this complex environment, they believed that more data need to be gathered.

Summary. From these studies it is evident that there is a lack of communication between SDs and HFEs that needs to be explored. From the studies conducted by Hammond et al. (1983) and Grudin and Poltrock (1989), there is an indication that when HFE help is available, it is not necessarily the type of help expected or considered useful.

THESIS OBJECTIVES

For this thesis, two assumptions were made:

1. Lack of communication is due to differences in the frames of reference of HFEs and SDs.
2. Differences in these frames of reference can be demonstrated.

To demonstrate differences in a frame of reference, a particular area of interest must be chosen. For this thesis, software development was the area of interest, in particular software development activities and the type of usability information required before a recommended change is made to a product.

By obtaining information on the software development activities from HFEs and SDs, it is believed that some insight can be provided into why there is a lack of communication. If HFEs and SDs disagree on the activities that are important or who should be involved in these activities, then this disagreement could be a basis for the lack of communication.

By determining what information SDs and HFEs believe is important at different points in the software development life cycle, insight can be gained into why HFE input is not considered useful by SDs. It may be that the information an HFE provides is the right information at the wrong time in the life cycle.

Thus, the objectives of this thesis were:

1. To develop an instrument which could be used to determine the differences in the frames of reference of HFEs and SDs.
2. To test the instrument.

INSTRUMENT DEVELOPMENT

A questionnaire was chosen as the instrument to be used. To develop the questionnaire, various questionnaire (Crocker and Algina, 1986; Edwards, 1957; Remmers, 1954) and job analysis (Brademas and Lowrey, 1984; Donnelly, 1983; Gael, 1983) literature sources were reviewed and the following steps were conducted.

Step 1: Develop a list of activities that are commonly performed using published literature on software design methodology.

By using the references in Table 6, a list of activities was developed. Refer to Table 7 for the list of activities developed.

Step 2: Develop a list of the types of information that HFEs could provide during software development using published literature on software design methodology and human factors references.

By using the references in Table 6 and Table 8, a list of the usability information that HFEs could provide during software development was created. Refer to Table 9 for the list of usability information developed.

Step 3: Verify that the terminology is clear and unambiguous using participants trained in software development and human factors engineering.

Six students from Virginia Polytechnic Institute and State University reviewed each of the lists and provided feedback. Based on their comments, the two lists were changed.

For the software development activities the following changes were made:

- The order of the activities was changed to match a software development life cycle.
- Each activity was changed to begin with a verb.

Table 6. References for Software Development Activities

Article	*Title*	*Type*
Blum (1984)	Three paradigms for developing information systems	Article
Carroll and Rosson (1985)	Usability specifications as a tool in iterative development	Chapter in book
Dandekar (1987)	A procedural approach to the evaluation of software development methodologies	Thesis
Enos and Tilburg (1981)	Software design	Article
Fruhauf and Jeppesen (1986)	Software development: The staircase approach	Article
Gould (1988)	How to design usable systems	Chapter in book
Hawryszkiewycz (1988)	Introduction to systems analysis and design	Book
Mantei and Teorey (1988)	Cost/benefit analysis for incorporating human factors in the software lifecycle	Article
Rowen (1990)	Software project management under incomplete and ambiguous specifications	Article
Rubinstein and Hersh (1984)	The human factor	Book
Schwartz (1975)	Construction of software: Problems and practicalities	Chapter in book
Shneiderman (1980)	Software psychology	Book

Table 7. Software Development Activities Developed from References

List from References
Define user
Problem definition
Market requirements
Build a prototype
Design iteration
Meetings with users
Product testing
Decide who users will be
Decide what the users will be doing with the system
Feasibility study
Design user interface
Write documentation
Code modules
Test modules
Test system
Decision on design alternatives

Table 8. References for Usability Information

Author	*Title*	*Type*
Holt and Stevenson (1977)	Human performance considerations in complex systems	Article
Marca (1984)	Applying software engineering principles	Book
Meister (1982)	The role of human factors in system development	Article
Meister and Rabideau (1967)	Human factors evaluation in system development	Book
Mittermeir, Roussopoulos, Yeh, and Ng (1990)	An integrated approach to requirements analysis	Chapter in book
Rogers and Armstrong (1977)	Use of human engineering standards in design.	Article
Sanders and McCormick (1987)	Human factors in engineering and design	Book
Sulack, Lindner, and Dietz (1989)	A new development rhythm for AS/400 software	Article

Table 9. Usability Information that HFEs Could Provide Developed from References

List from References
Kind of errors
Rate of errors
Number of errors
Time to recover from errors
Reacquisition of skills after time away from equipment
Motivation to use
System adaptation to a variety of tasks
User productivity
Performance data
Personal opinion
Expert human factors opinion
Expert computer science opinion
Design decisions of competitors
Designs of competitors

- Details were added to the statements to ensure consistent interpretation.

Refer to Table 10 for the list of software development activities that resulted from these changes.

For the usability information, details were added to the statements to ensure consistent interpretation. Refer to Table 11 for the list of usability information that resulted from these changes.

Step 4: Obtain feedback from questionnaire experts on the reasonableness of the questions and their format.

A. Bayer[1] (personal communication, January 29, 1991) and S. Gustafson[2] (personal communication, February 5, 1991) provided feedback on the questionnaire. From their input the following decisions were made:

- Changed from a seven-point rating scale for the activities to a five-point rating scale. This is due to the lack of experience of the participants. It is doubtful that they could discriminate to the level of detail presented in a seven-point scale.
- Changed from a seven-point rating scale for the usability information to a three-point rating scale. Again, this was due to the ability of the participants to discriminate as well as to the type of answers that were meaningful.

Step 5: Prepare the instrument for the experiment.

The "Method" section discusses how the instrument was prepared for the experiment.

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[1] Director of the Center for Survey Research at Virginia Polytechnic Institute and State University.

[2] Assistant Professor of Psychology at Virginia Polytechnic Institute and State University.

Table 10. Software Development Activities Developed from Feedback

Final List
Identify who the users will be (e.g., programmers, secretaries)
Define each user identified (e.g., level of education, computer sophistication)
Meet with the users
Identify who the customers will be (e.g., manufacturing, insurance)
Define each customer identified (e.g., number of employees, size of revenue)
Determine product requirements (i.e., user, market, customer)
Define the market the product will be sold into
Determine the feasibility of the product
Consider design alternatives
Determine the user interface design
Determine the product design
Develop the prototype
Test the prototype
Develop programs
Develop user documentation
Develop user training
Test software (functionality, reliability)
Test user documentation
Test user training
Test product with users

Table 11. Usability Information that HFEs Could Provide Developed from Feedback

Final List
Type of user errors
Frequency of user errors
Number of user errors
Time for user to recover from an error
Reacquisition of skills after time away from the software
Motivation to use the software
User productivity
Team member's opinion
User representative's opinion
Designs of competitors
Guidelines developed by human factors experts
Data from studies conducted on similar products or product features
Data from a market research project
Data from a study conducted with representative users

HYPOTHESES

For the software development activities, it was believed that the HFEs would rate the importance of the participation of product team members differently than SDs. For the usability information, it was believed that HFEs would rate the information needed to make a design decision differently than SDs.

METHOD

Participants

Because of the profiles HFEs and SDs have in industry, the following participants were recruited for the study.

HFEs. The HFEs were 33 students pursuing an M.S. or Ph.D. degree in Industrial and Systems Engineering with emphasis on human factors engineering at Virginia Polytechnic Institute and State University (Virginia Tech). All participants had to have completed the first semester of the program to participate. As discussed previously, HFEs typically have a master's or Ph.D. degree and since Virginia Tech's human factors program is considered by many to be among the best in the nation, participants with this educational background seemed most suited to the experiment. Three of the students participated in the pilot study. Participants in the pilot study and experiment were paid $4.00 each.

SDs. The SDs were 33 students pursuing an undergraduate degree in computer science at Virginia Tech. All participants had to be seniors in the program to participate. SDs typically have undergraduate degrees in mathematics, electrical engineering, or computer science. Computer science was chosen because it is the department within Virginia Tech recognized for software development training. Three of the students participated in the pilot study for which they were paid $4.00 each. Due to the difficulty of recruiting participants as well as feedback received from the pilot study, participants in the experiment received $5.00 each.

Equipment and Materials

Each participant was provided with the following materials:

- One of the background questionnaires
  - HFE background questionnaire (Appendix A)
  - SD background questionnaire (Appendix B)
- Software development questionnaire
  - Software development activities questionnaire (Appendix C)
  - Usability information questionnaire (Appendix D)
- Number 2 lead pencils

The questionnaires were numbered at the top according to the following:

- HFEs

HFE background questionnaire	1101-1130
Software development questionnaire	
Software development activities	1201-1230
Usability information	1301-1330

- SDs

SD background questionnaire	2101-2130
Software development questionnaire	
Software development activities	2201-2230
Usability information	2301-2330

The last two digits of the number indicated the participant's participation number. To ensure that each participant had the same participant number for each of the questionnaires, the questionnaires were stapled together in the following order: background questionnaire, software development activities questionnaire, usability information questionnaire. The software development questionnaire together with the usability information questionnaire were separated physically from the background questionnaire with a red divider page. In addition, the software development questionnaire and usability questionnaire were bound together with two gummed seals which kept them from being examined prematurely. The instructions for the usability information questionnaire were printed on colored paper. This served as a physical divider as well as a mental reminder to the participants that a different type of questionnaire was being presented to them. Verbal instructions were provided in addition to the written instructions (Appendix E).

Procedure

After the participants were seated, pencils and questionnaires were distributed. Verbal instructions were provided (Appendix E) before the participants began completing the background questionnaire. The experimenter answered questions as they arose. When all of the participants had completed the background questionnaire (reached the red page), further verbal instructions were presented. These instructions informed the participant about the two questionnaires they were about to answer. The participants were then asked to break the seals which bound the questionnaires together. The experimenter asked the participants to follow along as the description of the software development environment was read aloud. This verbalization of the description was done to ensure that everyone had read the description and understood it. Procedural reminders were issued verbally and the participants were given permission to complete the questionnaires. Upon completion of the questionnaires, the participants took the completed document to the experimenter.

Pilot study. The pilot study was conducted to:

- Determine the time necessary for completion.
- Ensure that having more than one person in the room at the same time was not distracting.

- Determine if the structure or content of the questionnaire needed to be modified.

Two sessions were scheduled, one for each educational area with three subjects each. The questionnaire was distributed to the participants and the time was recorded. The stated procedure was followed. Upon completion of the questionnaire, the experimenter recorded the participant's time and gave the follow-up questionnaire to the participant (Appendix F). When the participant had completed the follow-up questionnaire, he/she brought the questionnaire to the experimenter to receive payment.

The participants in both educational areas completed the questionnaire in less than 45 minutes which met the time requirement of less than one hour. The participants felt that having more than one person in the room was not a distraction, but they did feel that the number of people in the room should be less than four. Based upon their additional comments, the following modifications were made:

- Changes were made to the background questionnaires for clarification.
- Changes were made to the verbal instructions for clarification.
- More explanation was added to the instructions preceding the usability information questionnaire. Because of the increased wordage, a pink colored page was used instead of green, which was used in the pilot study. The change in the color of paper was necessary to improve readability.
- The number of people participating at one time was reduced to an absolute maximum of three with two people being the optimum.

Experiment. A room at Virginia Tech was used for data collection purposes. Up to three participants in one of the educational areas were tested at one time, with most tests consisting of two participants. The procedures previously stated were followed.

Data Input

Participants entered their responses on the questionnaires. Their responses were transferred by the experimenter to an optical scan (opscan) form. These forms were scanned by Measurement and Research Services at Virginia Tech. The data, then, were transferred to the universities mainframe for analysis with SAS (version 6.06.01) and the Comprehensive Questionnaire Analysis Program (CQAP).

Experimental Design

Background questionnaire. As stated, there was one background questionnaire for the HFEs (Appendix A) and one for the SDs (Appendix B). The information gathered from these questionnaires provided demographic data as well as information on the participant's knowledge of specific software industry terms. The participants were asked to indicate, by a check mark, their level of knowledge of these terms. Table 12 contains the table which the participants used to indicate their answers. For each software industry term, a contingency table was built (Table 13). Each cell in the contingency table contained the number of participants who gave that particular rating.

Software development activities questionnaire. A three-way mixed factor design was used for the software development activities (Figure 2). The three factors were:

1) Educational training (E) - HFE and SD.
2) Software development activities (A) - the 20 activities delineated in Table 10.

Table 12. Knowledge of Industry Terms - Table Participants Completed

	No Knowledge	Very Little Knowledge	Moderate Amount of Knowledge	Full Applied Knowledge
Human factors engineering				
End user				
Customer				
Training Developer				
Marketing specialist				
Knowledge worker				
Market environment				
Prototype				
Software product				
Iteration				
Task				
Usability				
Software lifecycle				
Systems design				
Software engineering				
Usability engineering				

Table 13. 4 x 2 Contingency Table for One of the Software Industry Terms

	Education		
Rating Categories	*HFE*	*SD*	*Combined*
No Knowledge	n_{11}	n_{12}	R_1
Very Little Knowledge	n_{21}	n_{22}	R_2
Moderate Amount of Knowledge	n_{31}	n_{32}	R_3
Full Applied Knowledge	n_{41}	n_{42}	R_4
Totals	$C_1=30$	$C_2=30$	$N=60$

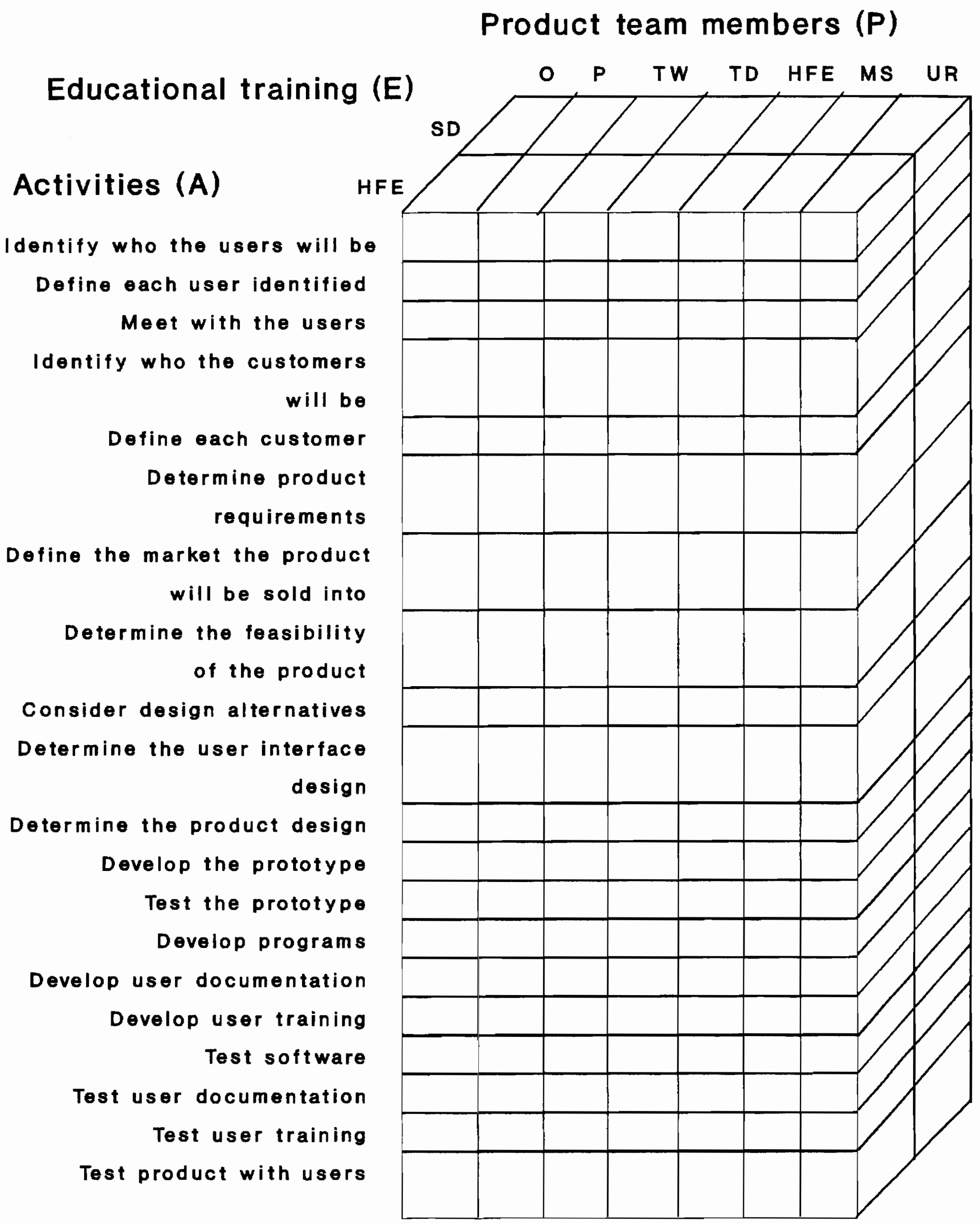

Figure 2. Experimental design for software development activities.

3) Product team members (P) - overall (O), programmers (P), technical writers (TW), training developers (TD), human factors engineers (HFE), marketing specialists (MS), and user representatives (UR).

For each of the cells, participants were asked to give an importance rating using a five-point rating scale. Refer to the questionnaire in Appendix C.

Usability information questionnaire. A three-way mixed factor design was used for the usability information required for design changes (Figure 3). The three factors were:

1) Educational training (E) - HFE and SD.
2) Usability information (U) - the 14 types of usability information delineated in Table 11.
3) Point in development (D) - no code has been written (NC), the code is being written (WC), after the code has been written (AC), and the product has been shipped (PS).

For each of the cells, participants were asked to determine if the supporting information would be enough to make a design change using a three-point rating scale. Refer to the questionnaire in Appendix D.

Data Analysis

Background questionnaire. Demographic profiles were developed from the data gathered from the participants. Percentages were calculated for each area surveyed. For the software industry terms, the data in the contingency table (Table 13) were used to perform a Sutcliffe (Sutcliffe, 1957) chi-square test. The results of the test were used to determine whether HFEs or SDs differ in their level of knowledge of the terms. X^2_{Total} was calculated first. If it was found to be significant at a level of significance of 0.05, then $X^2_{Education}$, X^2_{Rating}, and X^2_{ExR} were calculated (Table 14). In addition, for any term with a

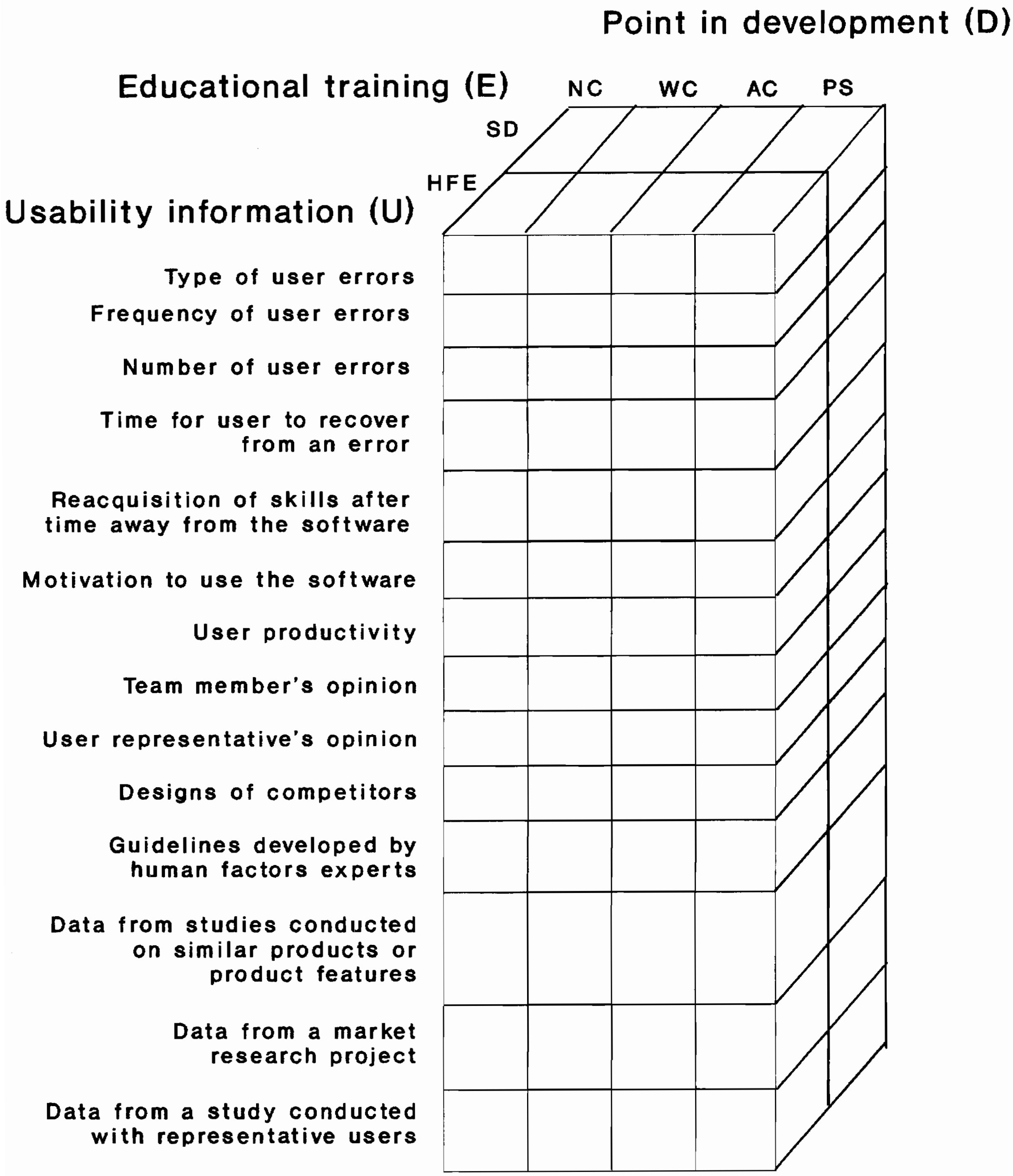

Figure 3. Experimental design for usability information.

Table 14. Sutcliffe Chi-Square Summary Table for the Software Industry Terms - Formulas Used

Source	*df*	X^2
Education (E)	1	$X^2_E = \sum^{e} (O_{i.} - E_{i.})^2 / E_{i.}$
Rating (R)	3	$X^2_R = \sum^{r} (O_{.j} - E_{.j})^2 / E_{.j}$
ExR	3	$X^2_{ExR} = \sum^{e} \sum^{r} (O_{ij} - E_{ij})^2 / E_{ij} - X^2_E - X^2_R$
Total	7	$X^2_{Total} = \sum^{e} \sum^{r} (O_{ij} - E_{ij})^2 / E_{ij}$

significant X^2, appropriate paired comparisons were performed using chi-square with $df = 1$. If the expected frequency was less than five, a binomial test ($p = q = {}^1/_2$) was performed.

Software development activities questionnaire. Two types of analyses were conducted on the data, interitem correlations and ANOVA.

Interitem correlations were performed to determine whether there were any activities that the participants from each of the educational training areas rated the same. Thus, for a given educational training and product team member, product-moment correlations were computed between pairs of activities. This resulted in 14 correlation matrices. SAS provided the probability that each of the correlations were significantly different from zero. Any probability that was less than or equal to the per comparison level of significance of 0.0003 (experiment-wise level of significance of 0.05) was determined to be statistically significant.

An ANOVA was performed to determine where the factors were significantly different. If any of the effects were significant, a Greenhouse-Geisser correction (Greenhouse and Geisser, 1959) was used to adjust the degrees of freedom), thus changing the critical value of *F*. For any significant interactions with the adjusted *df*s, simple-effect Fs and, where necessary, Newman-Keuls post-hoc tests were used to probe the results.

Usability information questionnaire. Two types of analyses were conducted on the data, interitem correlations and ANOVA.

Interitem correlations were performed to determine whether there were any types of usability information that the participants from each of the educational training areas rated the same. Thus, for a given educational training and point in development, product-moment correlations were computed between types of usability information. This resulted in eight correlation matrices. SAS provided the probability that each of the correlations was significantly different from zero. Any probability that was less than or equal to the per comparison level of significance of 0.0006 (experiment-wise level of significance of 0.05) was determined to be statistically significant.

An ANOVA was performed to determine where the factors were significantly different. For any significant interactions, simple-effect Fs and, where necessary, Newman-Keuls post-hoc tests were used to probe the results.

RESULTS - BACKGROUND QUESTIONNAIRE

Demographic Data

Demographic profiles were developed from the data gathered from the participants and Tables 15 and 16 were completed.

HFE results. As expected most of the participants were male (70%) and over 24 years of age (63%). Most of the undergraduate degrees were in psychology or industrial engineering and 30% were Virginia Tech (VT) undergraduates. Of the participants who had master's degrees (43%), most of these degrees (62%) were in industrial engineering with an emphasis in human factors. About half (54%) of the master's degrees were obtained from Virginia Tech (VT). About half (57%) the participants were currently working toward a master's degree. Surprisingly, 82% of the participants had taken a programming course. Half (50%) of the participants indicated having taken a computer course other than the ones listed. Many (47%) of these participants had taken a human-computer interaction class. The other computer classes listed varied from PC application software to simulation packages. However, as expected, few participants (30%) had any experience with software design outside of the university setting. Of these, half (50%) had been involved in writing software for non-personal uses. The remainder had been involved in other aspects of software design (e.g., interface design, usability testing).

SD results. As expected, most of the participants were male (90%) and between 22 and 24 years of age (57%). None of the participants had taken the human-computer interaction or introduction to human factors engineering classes. About half of the participants (53%) had some experience in software

Table 15. HFE Demographic Data

Age	*Sex*	*Undergraduate Degree from VT*	*Currently working on*	*Master's From VT*
37% 22-24	70% male	30% VT	57% Masters	54% VT
63% over 24	30% female	70% not VT	43% Ph.D.	46% not VT

Undergraduate Degree	*Master's Degree*	
23%		Psychology
23%	8%	Industrial Engineering
18%	8%	Other Engineering
10%	62%	Industrial Engineering with emphasis in Human Factors
8%		Human Factors/Ergonomics
3%	15%	Psychology with emphasis in Human Factors
3%		Other Engineering with emphasis in Human Factors
3%		Medicine/Physiology/Life Sciences
3%		Business
3%		Double major Medicine/Physiology/Life Sciences and Other
3%		Double major Computer Science and Other Engineering
	7%	Other

Area you are Interested in working	*Computer Courses*	*Any Experience in SW Design*
37% Ergonomics	87% Programming	27% yes
37% Hardware design	50% Other	73% no
27% Human computer interaction	27% Data bases	
27% Professor in HFE	20% Systems design	
20% Visual Displays	13% Operating systems	
17% Safety		
10% Audition		
7% Pursue a Ph.D.		
3% Rehabilitation		

Table 16. SD Demographic Data

Age	*Sex*	*Class Taken*
30% 18-21	90% male	100% Intro. to computer science
57% 22-24	10% female	100% Assembly and assemblers
13% over 24		100% Data structures and file management
		100% Operating systems
		100% Numerical methods
		97% Comparative languages
		50% Performance evaluation of computer systems
		47% Theory of computation
		43% Intro. to artificial intelligence
		40% Professionalism in computing
		40% Computer graphics
		37% Principles of computer architecture and operating systems
		37% Intro. to data base management
		27% Simulation and modeling
		23% Intro. to formal languages and automata theory
		20% Foundations of prog. languages and file management
		20% Data and algorithm analysis
		13% Computer organization
		13% Software engineering
		10% Information systems project
		3% Computer design and implementation
		0% Human-computer interaction
		0% Intro. to human factors engineering

Area you are Interested in working	*Any Experience in SW Design*
60% Software design	53% yes
40% Computing consulting	47% no
33% Business application programmer (MIS)	
30% Pursuing a masters degree	
17% Operating systems programmer	
10% Data base programmer	
3% Systems Analyst	
3% Education	

design outside the university setting. This experience varied greatly in terms of the types of applications, but the experience did provide them with an opportunity to work on an application designed for a specified set of users.

Software Industry Terms

For all 16 terms, X^2_{Total} was statistically significant, as was X^2_{Rating}. $X^2_{Education}$ was not significant. X^2_{ExR} was significant for only four terms: human factors engineering, marketing specialist, software life cycle, and usability engineering. Appendix G contains the summary tables for each of the 16 terms. The analysis indicates that HFEs and SDs had the same level of knowledge for 12 of the 16 terms. By analyzing the paired comparisons and the plots of the frequencies of the ratings (Appendix G), it was determined that for eight of the terms (end user, customer, prototype, software product, iteration, usability, systems design, and task) the participants had a "moderate amount of" or "full applied" knowledge of the terms. For three of the terms (training developer, knowledge worker, and market environment), the participants indicated that they had "no" or "very little" knowledge of the terms. For one term (software engineering), the participants indicated that they had "very little" or "moderate amount of" knowledge of the terms.

The four terms with a significant interaction effect were analyzed by examining the plots of the main effect of education (E) for each of the ratings (r_i) and the plots of the main effect of rating (R) for each level of education (e_i) (Figures 4 - 7) and performing the appropriate paired comparisons. This analysis indicates that an HFE has "full applied" knowledge of the term human factors engineering, while an SD has "no" or "very little" knowledge of the term.

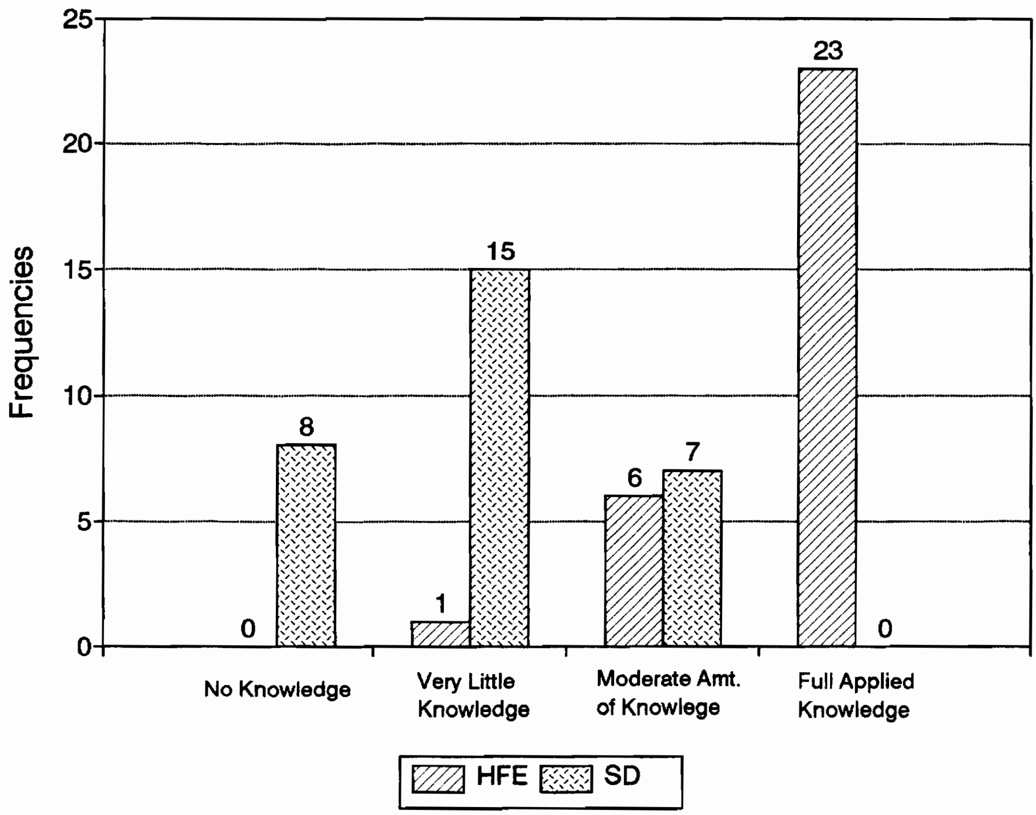

Figure 4. Frequency histogram of software industry term - human factors engineering.

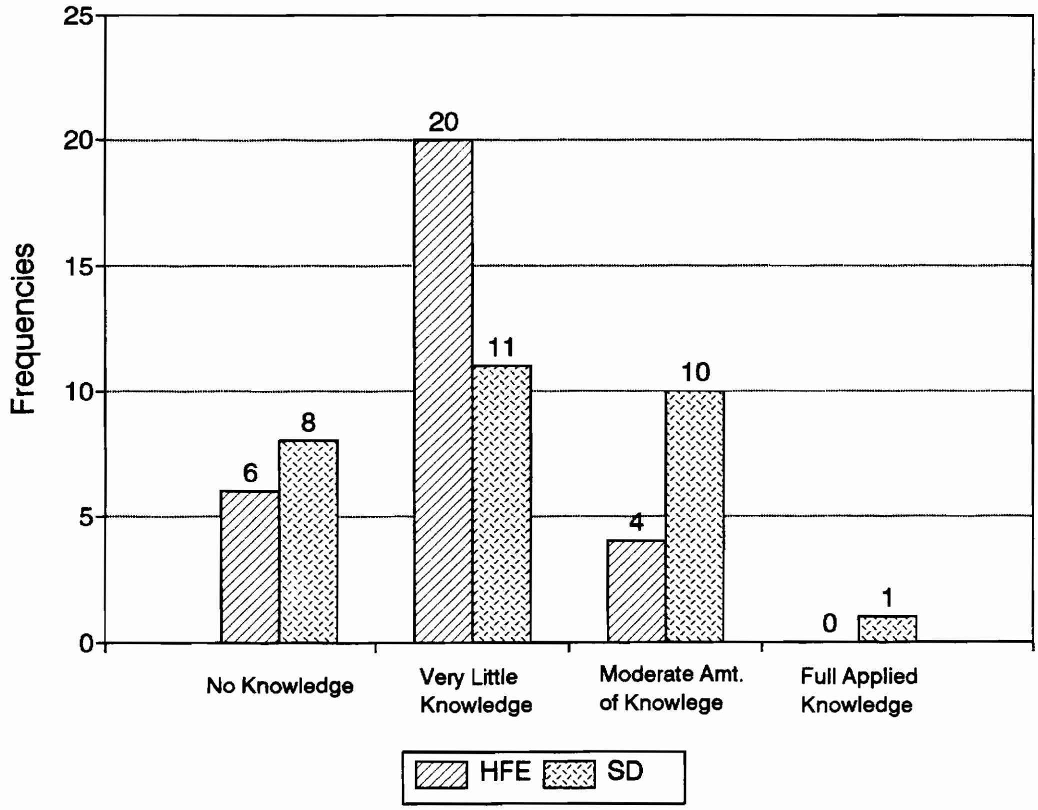

Figure 5. Frequency histogram of software industry term - marketing specialist.

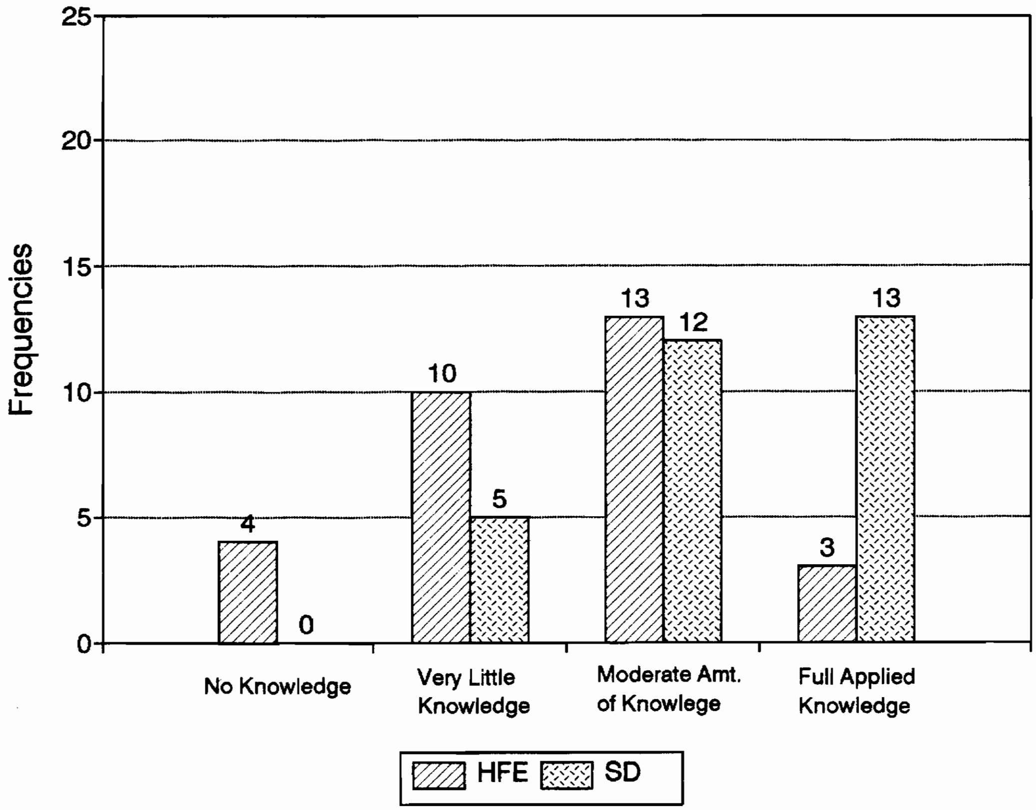

Figure 6. Frequency histogram of software industry term - software lifecycle.

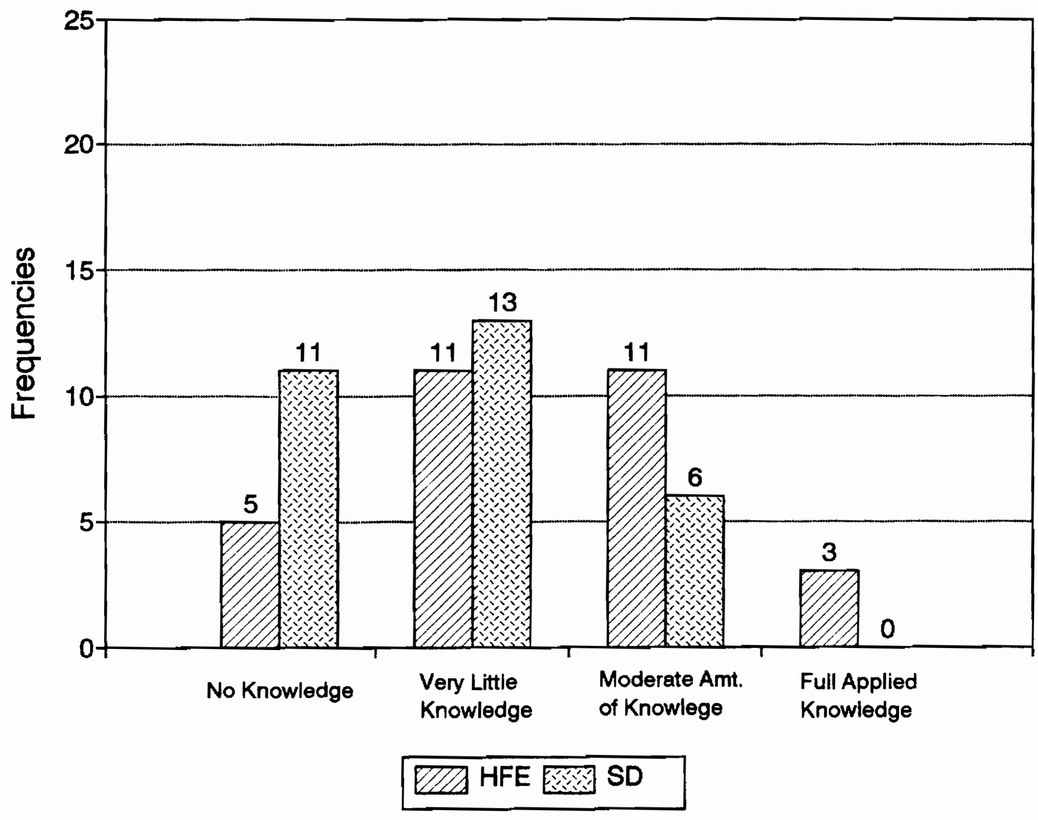

Figure 7. Frequency histogram of software industry term - usability engineering.

For the term marketing specialist, an HFE has "no" or "very little" knowledge of the term while an SD has "very little" or "moderate amount of" knowledge of the term. For the term software life cycle, an HFE has "very little" or "moderate amount of" knowledge of the term, while an SD has "no" or "very little" knowledge of the term. For the term usability engineering, an HFE has "very little" to "moderate amount of" knowledge, while an SD has "no" or "very little" knowledge of the term.

RESULTS - SOFTWARE DEVELOPMENT ACTIVITIES QUESTIONNAIRE

Interitem Correlation

HFE results. The correlation tables (Tables 17 - 23) indicate which activities were correlated highly ($p \leq 0.0003$). Table 24 contains the total number of interitem correlations that were correlated highly ($p \leq 0.0003$) summed across all of the product team members for HFEs. For instance "identify who the users will be" (Activity 1) and "define each user identified" (Activity 2) were correlated highly ($p \leq 0.0003$) for six out of seven product team members. As Table 24 indicates, the following activities were correlated highly for at least five of the product team members:

- Identify who the users will be,
  Define each user identified
- Identify who the customers will be,
  Define each customer identified
- Develop user training,
  Develop user documentation
- Test user documentation,
  Test user training,
  Test product with users

SD results. The correlation tables (Tables 25 - 31) indicate which activities were correlated highly ($p \leq 0.0003$). Table 32 contains the total number of interitem correlations that were correlated highly ($p \leq 0.0003$) summed across all of the product team members for SDs. As Table 32 indicates, the following activities were correlated highly for at least five of the product team members:

- Identify who the users will be,
  Define each user identified
- Develop the prototype,
  Develop programs

Table 17. HFE Correlation Matix for Software Development Activity - Overall

Boxes with double-lined borders indicate p<= 0.0003.

		1	2	3	4	5	6	7	8	9	10
Identify who the users will be	1	1 0									
Define each user identified	2	0.22942 0.2226	1 0								
Meet with the users	3	0.17104 0.3662	0.0981 0.6061	1 0							
Identify who the customers will be	4	0.4247 0.0193	0.20878 0.2682	0.40767 0.0253	1 0						
Define each customer	5	0.03211 0.8662	0.46038 0.0105	0.01961 0.9181	0.41883 0.0212	1 0					
Determine product requirements	6	0.02466 0.8971	0.3111 0.0943	0.37652 0.0403	0.17203 0.3634	-0.00396 0.9834	1 0				
Define the market the product will be sold into	7	0.34641 0.0608	0.13245 0.4853	0.2116 0.2616	0.46705 0.0093	0.09269 0.6262	-0.07117 0.7086	1 0			
Determine the feasibility of the product	8	0.16953 0.3705	0.30558 0.1006	0.41422 0.0229	0.30121 0.1058	-0.02722 0.8865	0.06867 0.7184	0.48938 0.0061	1 0		
Consider design alternatives	9	0.04152 0.8275	0.23815 0.205	0.36778 0.0456	0.11337 0.5509	-0.13665 0.4715	0.1638 0.3871	0.41953 0.021	0.59833 0.0005	1 0	
Determine the user interface design	10	0.13484 0.4774	0.19334 0.306	0.45302 0.0119	0.14317 0.4504	0.17318 0.3601	0.507 0.0042	0 1	0.30206 0.1047	0.28694 0.1242	1 0
Determine the product design	11	0.41818 0.0215	0.27113 0.1473	0.38872 0.0338	0.35851 0.0517	-0.01459 0.939	0.25776 0.1691	0.3674 0.0458	0.64948 0.0001	0.49072 0.0059	0.58226 0.0007
Develop the prototype	12	0.31872 0.0861	0.08602 0.6513	0.29776 0.11	0.26731 0.1533	-0.08729 0.6465	0.07165 0.7067	0.21649 0.2505	0.49264 0.0057	0.57607 0.0009	0.46768 0.0092
Test the prototype	13	0.13484 0.4774	0.07734 0.6846	0.28828 0.1224	0.10908 0.5661	-0.15153 0.4241	0.2161 0.2514	0.12975 0.4944	0.17961 0.3423	0.46191 0.0102	0.43182 0.0172
Develop programs	14	0.39575 0.0304	0.19114 0.3116	0.47076 0.0087	0.44862 0.0129	0.02675 0.8884	0.05906 0.7566	0.42089 0.0206	0.48173 0.007	0.38487 0.0357	0.36511 0.0473
Develop user documentation	15	-0.09645 0.6121	0.11063 0.5606	0.07364 0.6989	0.20481 0.2776	0.01548 0.9353	0.10107 0.5951	0 1	0.25694 0.1705	0.41049 0.0242	0.45518 0.0115
Develop user training	16	-0.09796 0.6065	0.11237 0.5544	0.11968 0.5287	0.11293 0.5524	-0.08807 0.6435	0.11352 0.5503	-0.11312 0.5517	0.42468 0.0193	0.41084 0.0241	0.48214 0.007
Test software	17	0.18353 0.3316	-0.05263 0.7824	0.32232 0.0824	0 1	-0.29464 0.114	-0.05656 0.7666	0.39736 0.0297	0.52782 0.0027	0.61919 0.0003	0.27068 0.148
Test user documentation	18	-0.01982 0.9172	0.36381 0.0481	0.06054 0.7506	0.04209 0.8252	0.19412 0.304	0.07575 0.6907	-0.05722 0.7639	0.0168 0.9298	0.23869 0.204	0.29401 0.1148
Test user training	19	-0.03525 0.8533	0.283 0.1297	0.26912 0.1504	0.14969 0.4298	0.25179 0.1795	0.16076 0.3961	-0.10174 0.5927	0.33716 0.0685	0.28172 0.1315	0.5406 0.002
Test product with users	20	-0.04152 0.8275	0.4763 0.0078	0.279 0.1354	0.45346 0.0118	0.23665 0.208	0.22011 0.2425	0.11987 0.5281	0.15587 0.4108	0.2931 0.116	0.13297 0.4836

Table 17 (Continued). HFE Correlation Matrix for Software Development Activity - Overall

Boxes with double-lined borders indicate p<= 0.0003.

Identify who the users will be	1										
Define each user identified	2										
Meet with the users	3										
Identify who the customers will be	4										
Define each customer	5										
Determine product requirements	6										
Define the market the product will be sold into	7										
Determine the feasibility of the product	8										
Consider design alternatives	9										
Determine the user interface design	10										
Determine the product design	11	1 0									
Develop the prototype	12	0.6221 0.0002	1 0								
Test the prototype	13	0.36775 0.0456	0.78368 0.0001	1 0							
Develop programs	14	0.6154 0.0003	0.48227 0.007	0.36511 0.0473	1 0						
Develop user documentation	15	0.30688 0.099	0.39781 0.0295	0.29262 0.1166	0.37165 0.0432	1 0					
Develop user training	16	0.47201 0.0085	0.40957 0.0246	0.25098 0.181	0.30403 0.1024	0.68974 0.0001	1 0				
Test software	17	0.47969 0.0073	0.55915 0.0013	0.38668 0.0348	0.45395 0.0117	0.30424 0.1021	0.0899 0.6366	1 0			
Test user documentation	18	0.22525 0.2314	0.10963 0.5641	0.22719 0.2273	0.20025 0.2887	0.4923 0.0057	0.43304 0.0168	0.11369 0.5497	1 0		
Test user training	19	0.40052 0.0283	0.27423 0.1425	0.09505 0.6173	0.28998 0.1201	0.5184 0.0033	0.72854 0.0001	0.08086 0.671	0.70913 0.0001	1 0	
Test product with users	20	0.18874 0.3179	0.18294 0.3332	0.37793 0.0395	0.39352 0.0314	0.4155 0.0224	0.38237 0.037	-0.04763 0.8026	0.56381 0.0012	0.37685 0.0401	1 0
		11	12	13	14	15	16	17	18	19	20

Table 18. HFE Correlation Matrix for Software Development Activity - Programmer

Boxes with double-lined borders indicate p<= 0.0003.

Identify who the users will be	1	1 0									
Define each user identified	2	0.82974 0.0001	1 0								
Meet with the users	3	0.62627 0.0002	0.56863 0.001	1 0							
Identify who the customers will be	4	0.7178 0.0001	0.61891 0.0003	0.50683 0.0043	1 0						
Define each customer	5	0.5119 0.0038	0.49144 0.0058	0.45263 0.012	0.50962 0.004	1 0					
Determine product requirements	6	0.51875 0.0033	0.51193 0.0038	0.46173 0.0102	0.52841 0.0027	0.21355 0.2572	1 0				
Define the market the product will be sold into	7	0.52917 0.0026	0.57038 0.001	0.43364 0.0167	0.59256 0.0006	0.63814 0.0001	0.44266 0.0143	1 0			
Determine the feasibility of the product	8	0.22121 0.2401	0.29732 0.1106	0.13971 0.4615	0.14543 0.4432	0.39634 0.0301	0.1552 0.4128	0.31778 0.087	1 0		
Consider design alternatives	9	0.23026 0.2209	0.31105 0.0943	0.22569 0.2305	0 1	0.31599 0.0889	0.3859 0.0352	0.41832 0.0214	0.60184 0.0004	1 0	
Determine the user interface design	10	0.35088 0.0573	0.38992 0.0332	0.24281 0.196	0.29814 0.1095	0.23744 0.2064	0.23547 0.2103	0.39241 0.032	0.19588 0.2996	0.33301 0.0722	1 0
Determine the product design	11	0.40789 0.0253	0.52026 0.0032	0.36638 0.0464	0.23843 0.2045	0.31038 0.0951	0.30365 0.1028	0.55296 0.0015	0.40726 0.0255	0.47549 0.0079	0.46113 0.0103
Develop the prototype	12	-0.09878 0.6035	0.13925 0.463	0.02994 0.8752	-0.06054 0.7506	0.00931 0.961	0.00611 0.9744	-0.01722 0.928	-0.07648 0.6879	0.1437 0.4487	0.10873 0.5674
Test the prototype	13	0.44466 0.0138	0.40355 0.027	0.15758 0.4056	0.22763 0.2264	0.35895 0.0514	0.14936 0.4308	0.38846 0.0339	0.53344 0.0024	0.36883 0.0449	0.30979 0.0957
Develop programs	14	-0.14112 0.457	-0.15272 0.4204	0.0591 0.7564	0.03735 0.8446	-0.09194 0.6289	-0.1282 0.4996	-0.31163 0.0937	-0.15892 0.4016	-0.08183 0.6673	0.109 0.5664
Develop user documentation	15	0.41711 0.0218	0.3778 0.0396	0.08997 0.6363	0.17871 0.3447	0.01 0.9582	-0.01804 0.9246	0.13554 0.4751	0.30674 0.0992	0.15424 0.4158	0.33553 0.0699
Develop user training	16	0.66882 0.0001	0.64776 0.0001	0.28221 0.1308	0.48681 0.0064	0.27375 0.1432	0.15929 0.4005	0.31512 0.0899	0.28346 0.129	0.09807 0.6061	0.29016 0.1198
Test software	17	0.30103 0.106	0.34696 0.0603	0.26854 0.1513	0.34449 0.0623	0.40529 0.0263	0.36414 0.0479	0.24208 0.1975	0.15897 0.4014	0.12579 0.5077	0.13192 0.4871
Test user documentation	18	0.61878 0.0003	0.50715 0.0042	0.27347 0.1437	0.42293 0.0199	0.35537 0.054	0.14451 0.4461	0.34854 0.0591	0.40879 0.0249	0.24947 0.1837	0.35238 0.0562
Test user training	19	0.64399 0.0001	0.53945 0.0021	0.30889 0.0967	0.42047 0.0207	0.31156 0.0937	0.19404 0.3042	0.31566 0.0893	0.34457 0.0622	0.23813 0.2051	0.33132 0.0737
Test product with users	20	0.55857 0.0013	0.51809 0.0034	0.47022 0.0087	0.48861 0.0062	0.56097 0.0013	0.2665 0.1546	0.58355 0.0007	0.37429 0.0416	0.18108 0.3383	0.34543 0.0615
		1	2	3	4	5	6	7	8	9	10

Table 18 (Continued). HFE Correlation Matrix for Software Development Activity - Programmer

Boxes with double-lined borders indicate p<= 0.0003.

		11	12	13	14	15	16	17	18	19	20
Identify who the users will be	1										
Define each user identified	2										
Meet with the users	3										
Identify who the customers will be	4										
Define each customer	5										
Determine product requirements	6										
Define the market the product will be sold into	7										
Determine the feasibility of the product	8										
Consider design alternatives	9										
Determine the user interface design	10										
Determine the product design	11	1 0									
Develop the prototype	12	0.24341 0.1949	1 0								
Test the prototype	13	0.56277 0.0012	-0.07993 0.6746	1 0							
Develop programs	14	-0.1403 0.4596	0.24604 0.19	-0.10883 0.567	1 0						
Develop user documentation	15	0.31847 0.0863	-0.10702 0.5735	0.4911 0.0059	-0.08544 0.6535	1 0					
Develop user training	16	0.31428 0.0908	-0.23254 0.2162	0.46158 0.0102	-0.20866 0.2685	0.74527 0.0001	1 0				
Test software	17	0.08682 0.6483	0.27286 0.1446	0.35794 0.0521	-0.01938 0.9191	0.04003 0.8336	0.123 0.5173	1 0			
Test user documentation	18	0.27018 0.1487	-0.34825 0.0593	0.53171 0.0025	-0.13221 0.4862	0.64102 0.0001	0.7803 0.0001	0.26476 0.1574	1 0		
Test user training	19	0.33944 0.0665	-0.29759 0.1102	0.50941 0.004	-0.06564 0.7304	0.59064 0.0006	0.81771 0.0001	0.16582 0.3812	0.93711 0.0001	1 0	
Test product with users	20	0.4631 0.01	-0.19357 0.3054	0.54846 0.0017	-0.09762 0.6078	0.22444 0.2331	0.52571 0.0028	0.38494 0.0357	0.6962 0.0001	0.66723 0.0001	1 0

Table 19. HFE Correlation Matrix for Software Development Activity - Technical Writer

Boxes with double-lined borders indicate p<= 0.0003.

Identify who the users will be	1	1 0									
Define each user identified	2	0.80445 0.0001	1 0								
Meet with the users	3	0.08956 0.6379	0.08129 0.6694	1 0							
Identify who the customers will be	4	0.40537 0.0263	0.55441 0.0015	0.23851 0.2043	1 0						
Define each customer	5	0.30405 0.1024	0.30863 0.097	0.15765 0.4054	0.65409 0.0001	1 0					
Determine product requirements	6	0 1	0.08832 0.6426	0.23435 0.2126	0.24107 0.1994	0.41111 0.024	1 0				
Define the market the product will be sold into	7	0.29579 0.1125	0.32779 0.077	0.27029 0.1486	0.4046 0.0266	0.5999 0.0005	0.58736 0.0006	1 0			
Determine the feasibility of the product	8	-0.01721 0.9281	-0.10542 0.5793	0.35602 0.0535	0.16625 0.3799	0.22718 0.2273	0.66313 0.0001	0.51365 0.0037	1 0		
Consider design alternatives	9	-0.20197 0.2845	-0.19025 0.3139	0.33766 0.068	0.16147 0.394	0.33936 0.0666	0.57652 0.0009	0.50303 0.0046	0.41358 0.0231	1 0	
Determine the user interface design	10	0.15177 0.4234	0.20432 0.2788	0.12959 0.4949	0.21806 0.247	0.13358 0.4816	0.41157 0.0238	0.29772 0.1101	0.38496 0.0357	0.41279 0.0234	1 0
Determine the product design	11	0.19487 0.3021	0.2318 0.2178	0.20944 0.2667	0.33134 0.0737	0.29625 0.1119	0.35398 0.055	0.27651 0.1391	0.26492 0.1571	0.55936 0.0013	0.65461 0.0001
Develop the prototype	12	0.22237 0.2376	0.18948 0.3159	0.23368 0.2139	0.20749 0.2712	0.03914 0.8373	0.31737 0.0875	0.12093 0.5244	0.38444 0.0359	0.34631 0.0608	0.69462 0.0001
Test the prototype	13	0.26276 0.1607	0.25835 0.1681	0.25887 0.1672	0.48006 0.0073	0.46254 0.0101	0.45004 0.0126	0.34074 0.0654	0.42278 0.0199	0.51301 0.0037	0.66533 0.0001
Develop programs	14	0.13957 0.462	0.12404 0.5137	0.16042 0.3971	0.17936 0.3429	0.18427 0.3297	0.32371 0.081	0.25339 0.1767	0.33685 0.0687	0.31948 0.0853	0.70098 0.0001
Develop user documentation	15	-0.13957 0.462	0.02111 0.9118	0.29793 0.1098	0.06915 0.7165	0 1	0.0996 0.6005	0.02633 0.8902	0.02642 0.8898	0.15034 0.4278	0.00777 0.9675
Develop user training	16	0.08528 0.6541	0.1935 0.3056	-0.10502 0.5807	0.03961 0.8354	-0.18765 0.3207	0.09129 0.6314	-0.33176 0.0733	-0.20178 0.2849	-0.04306 0.8213	0.35593 0.0536
Test software	17	0.17139 0.3651	0.08675 0.6485	-0.00433 0.9819	0.23515 0.211	0.31331 0.0918	0.47043 0.0087	0.26671 0.1542	0.47667 0.0077	0.39143 0.0324	0.53266 0.0024
Test user documentation	18	0.53718 0.0022	0.64252 0.0001	-0.00653 0.9727	0.44111 0.0147	0.26266 0.1608	0.0284 0.8816	0.36495 0.0474	0.04143 0.8279	0.01473 0.9384	0.36094 0.05
Test user training	19	0.28345 0.129	0.32914 0.0757	-0.15331 0.4186	0.17967 0.3421	0.10273 0.5891	0.14278 0.4516	0.0684 0.7195	0.00947 0.9604	0.13807 0.4669	0.60126 0.0004
Test product with users	20	0.22799 0.2256	0.27781 0.1372	0.27036 0.1485	0.43927 0.0152	0.26755 0.1529	0.39771 0.0295	0.36433 0.0478	0.33566 0.0698	0.49457 0.0055	0.55684 0.0014
		1	2	3	4	5	6	7	8	9	10

Table 19 (Continued). HFE Correlation Matrix for Software Development Activity - Technical Writer

Boxes with double-lined borders indicate p<= 0.0003.

		11	12	13	14	15	16	17	18	19	20
Identify who the users will be	1										
Define each user identified	2										
Meet with the users	3										
Identify who the customers will be	4										
Define each customer	5										
Determine product requirements	6										
Define the market the product will be sold into	7										
Determine the feasibility of the product	8										
Consider design alternatives	9										
Determine the user interface design	10										
Determine the product design	11	1 0									
Develop the prototype	12	0.72895 0.0001	1 0								
Test the prototype	13	0.83635 0.0001	0.82127 0.0001	1 0							
Develop programs	14	0.53491 0.0023	0.76436 0.0001	0.66396 0.0001	1 0						
Develop user documentation	15	0.09973 0.6	-0.01517 0.9366	0.03362 0.86	-0.01786 0.9254	1 0					
Develop user training	16	0.20773 0.2707	0.27813 0.1367	0.24649 0.1891	0.28641 0.1249	0.16366 0.3875	1 0				
Test software	17	0.73736 0.0001	0.75462 0.0001	0.81931 0.0001	0.57183 0.001	0.06072 0.7499	0.21644 0.2506	1 0			
Test user documentation	18	0.31146 0.0939	0.28442 0.1277	0.38337 0.0365	0.31564 0.0893	0.04073 0.8308	0.13998 0.4607	0.29719 0.1107	1 0		
Test user training	19	0.42565 0.019	0.44319 0.0142	0.50603 0.0043	0.50558 0.0044	-0.0256 0.8932	0.70386 0.0001	0.43284 0.0169	0.65318 0.0001	1 0	
Test product with users	20	0.55947 0.0013	0.46128 0.0103	0.63457 0.0002	0.34841 0.0592	0.12964 0.4947	0.29704 0.1109	0.56944 0.001	0.67451 0.0001	0.62723 0.0002	1 0
		11	12	13	14	15	16	17	18	19	20

Table 20. HFE Correlation Matrix for Software Development Activity - Training Developer

Boxes with double-lined borders indicate p<= 0.0003.

Identify who the users will be	1	1 0									
Define each user identified	2	0.78129 0.0001	1 0								
Meet with the users	3	0.02158 0.9099	0.02521 0.8948	1 0							
Identify who the customers will be	4	0.37178 0.0431	0.32303 0.0817	0.11462 0.5464	1 0						
Define each customer	5	0.15556 0.4117	0.27254 0.1451	0.03066 0.8722	0.62037 0.0003	1 0					
Determine product requirements	6	0.03155 0.8686	-0.03685 0.8467	-0.01545 0.9354	0.37645 0.0403	0.5012 0.0048	1 0				
Define the market the product will be sold into	7	0.04327 0.8204	0.07582 0.6905	-0.15544 0.4121	0.42685 0.0187	0.64561 0.0001	0.44927 0.0128	1 0			
Determine the feasibility of the product	8	-0.13503 0.4768	-0.26453 0.1578	-0.05156 0.7867	0.18474 0.3284	0.23265 0.216	0.51844 0.0033	0.52842 0.0027	1 0		
Consider design alternatives	9	-0.09073 0.6335	-0.15896 0.4015	-0.16665 0.3788	0.48189 0.007	0.3091 0.0965	0.3942 0.0311	0.46227 0.0101	0.5534 0.0015	1 0	
Determine the user interface design	10	0.07011 0.7128	-0.13006 0.4933	-0.13332 0.4825	0.49597 0.0053	0.37942 0.0386	0.33662 0.0689	0.54025 0.0021	0.44009 0.0149	0.82325 0.0001	1 0
Determine the product design	11	0.13168 0.4879	-0.02977 0.8759	-0.13732 0.4693	0.48504 0.0066	0.20671 0.2731	0.24178 0.198	0.40728 0.0255	0.55645 0.0014	0.82987 0.0001	0.76099 0.0001
Develop the prototype	12	0.2089 0.2679	0.09111 0.6321	-0.13043 0.4921	0.50271 0.0046	0.27261 0.145	0.37938 0.0387	0.56665 0.0011	0.56476 0.0011	0.77819 0.0001	0.70342 0.0001
Test the prototype	13	0.31215 0.0931	0.15216 0.4222	-0.0927 0.6261	0.52405 0.003	0.42257 0.02	0.24462 0.1926	0.57094 0.001	0.36995 0.0442	0.59979 0.0005	0.65293 0.0001
Develop programs	14	0.29418 0.1146	0.12154 0.5223	-0.31148 0.0938	0.36748 0.0457	0.25007 0.1826	0.2787 0.1359	0.49272 0.0057	0.44298 0.0142	0.61705 0.0003	0.53372 0.0024
Develop user documentation	15	0.48186 0.007	0.37991 0.0384	0.03894 0.8381	0.23765 0.206	0.18828 0.3191	0.07763 0.6835	0.35792 0.0521	0.18228 0.335	0.37211 0.0429	0.42793 0.0183
Develop user training	16	-0.07464 0.6951	-0.07133 0.708	0.54838 0.0017	0.24197 0.1977	0.16389 0.3868	0.16032 0.3974	0.03665 0.8475	0.07025 0.7122	0.11527 0.5441	0.14671 0.4392
Test software	17	0.36704 0.046	0.14971 0.4297	-0.21974 0.2433	0.43764 0.0156	0.34354 0.0631	0.15017 0.4283	0.53504 0.0023	0.44542 0.0136	0.40042 0.0283	0.4769 0.0077
Test user documentation	18	0.2371 0.2071	0.25707 0.1702	-0.01719 0.9282	0.33803 0.0677	0.51969 0.0032	0.38141 0.0376	0.4997 0.0049	0.33108 0.0739	0.22497 0.232	0.25946 0.1662
Test user training	19	0.53529 0.0023	0.65075 0.0001	-0.04415 0.8168	0.42066 0.0206	0.4676 0.0092	0.22879 0.224	0.3172 0.0876	0.08047 0.6725	-0.03585 0.8508	0.01476 0.9383
Test product with users	20	0.41828 0.0214	0.45705 0.0111	-0.03635 0.8488	0.5938 0.0005	0.56077 0.0013	0.35746 0.0525	0.41304 0.0233	0.18267 0.334	0.13546 0.4754	0.22923 0.223
		1	2	3	4	5	6	7	8	9	10

Table 20 (Continued). HFE Correlation Matrix for Software Development Activity - Training Developer

Boxes with double-lined borders indicate p<= 0.0003.

		11	12	13	14	15	16	17	18	19	20
Identify who the users will be	1										
Define each user identified	2										
Meet with the users	3										
Identify who the customers will be	4										
Define each customer	5										
Determine product requirements	6										
Define the market the product will be sold into	7										
Determine the feasibility of the product	8										
Consider design alternatives	9										
Determine the user interface design	10										
Determine the product design	11	1 0									
Develop the prototype	12	0.85427 0.0001	1 0								
Test the prototype	13	0.70768 0.0001	0.7906 0.0001	1 0							
Develop programs	14	0.65801 0.0001	0.78761 0.0001	0.7024 0.0001	1 0						
Develop user documentation	15	0.42158 0.0203	0.46919 0.0089	0.4879 0.0062	0.4057 0.0261	1 0					
Develop user training	16	0.07555 0.6915	0.05923 0.7559	0.08744 0.6459	-0.00653 0.9727	0.30611 0.0999	1 0				
Test software	17	0.59314 0.0006	0.5712 0.001	0.7937 0.0001	0.60544 0.0004	0.42055 0.0207	0.08883 0.6407	1 0			
Test user documentation	18	0.20973 0.266	0.25775 0.1691	0.42867 0.0181	0.20768 0.2708	0.62358 0.0002	0.28639 0.125	0.44542 0.0136	1 0		
Test user training	19	0.02389 0.9003	0.12287 0.5177	0.31675 0.0881	0.02891 0.8795	0.41892 0.0212	0.15267 0.4206	0.35157 0.0568	0.68946 0.0001	1 0	
Test product with users	20	0.19854 0.2929	0.22199 0.2384	0.46782 0.0091	0.11036 0.5616	0.27393 0.143	0.06857 0.7188	0.41216 0.0236	0.66622 0.0001	0.83493 0.0001	1 0

Table 21. HFE Correlation Matrix for Software Development Activity - Human Factors Engineer

Boxes with double-lined borders indicate p<= 0.0003.

Activity		1	2	3	4	5	6	7	8	9	10
Identify who the users will be	1	1									
		0									
Define each user identified	2	0.84688	1								
		0.0001	0								
Meet with the users	3	0.36916	0.41865	1							
		0.0447	0.0213	0							
Identify who the customers will be	4	0.57355	0.46103	0.24113	1						
		0.0009	0.0103	0.1993	0						
Define each customer	5	0.39902	0.39901	0.01488	0.65539	1					
		0.0289	0.0289	0.9378	0.0001	0					
Determine product requirements	6	0.32868	0.39148	0.37041	0.426	0.5236	1				
		0.0762	0.0324	0.0439	0.0189	0.003	0				
Define the market the product will be sold into	7	0.33523	0.24063	-0.1536	0.51382	0.72233	0.32988	1			
		0.0702	0.2002	0.4177	0.0037	0.0001	0.075	0			
Determine the feasibility of the product	8	0.25965	0.152	-0.06842	0.33848	0.38856	0.33807	0.35055	1		
		0.1659	0.4226	0.7194	0.0673	0.0338	0.0677	0.0575	0		
Consider design alternatives	9	-0.04251	0.04946	0.23323	0.04801	-0.04858	0.3545	-0.31865	0.30074	1	
		0.8235	0.7952	0.2148	0.8011	0.7988	0.0546	0.0861	0.1063	0	
Determine the user interface design	10	-0.08563	-0.09798	-0.12892	-0.20922	-0.26465	-0.12055	-0.39324	0.13374	0.58712	1
		0.6528	0.6065	0.4972	0.2672	0.1576	0.5257	0.0316	0.4811	0.0006	0
Determine the product design	11	0.02096	-0.06596	-0.15529	0.12072	0.23541	0.01248	0.34768	0.61216	0.05965	0.09285
		0.9125	0.7291	0.4126	0.5251	0.2105	0.9478	0.0598	0.0003	0.7542	0.6256
Develop the prototype	12	-0.19211	-0.14804	0.1196	-0.27396	-0.19993	0.22884	-0.10346	0.28288	0.35148	0.12157
		0.3091	0.435	0.529	0.1429	0.2895	0.2238	0.5864	0.1298	0.0568	0.5222
Test the prototype	13	-0.23399	-0.14024	0.06798	-0.21961	-0.22096	0.03097	-0.37243	0.12506	0.62894	0.57582
		0.2133	0.4598	0.7211	0.2436	0.2406	0.8709	0.0427	0.5102	0.0002	0.0009
Develop programs	14	-0.0674	-0.09398	-0.12108	0.03697	0.02171	0.1196	0.00726	0.28827	0.24857	0.37164
		0.7234	0.6213	0.5239	0.8462	0.9093	0.529	0.9696	0.1224	0.1853	0.0432
Develop user documentation	15	0.34999	0.26316	0.09429	0.06352	0.06181	0.17435	-0.03358	0.31922	0.37127	0.47919
		0.058	0.16	0.6202	0.7388	0.7456	0.3568	0.8602	0.0855	0.0434	0.0074
Develop user training	16	0.39753	0.34655	0.0735	0.10792	0.18038	0.22481	0.00908	0.3725	0.41712	0.51581
		0.0296	0.0606	0.6995	0.5703	0.3401	0.2323	0.962	0.0426	0.0218	0.0035
Test software	17	-0.2146	-0.30164	-0.0978	0.0711	0.07803	0.2712	0.15687	0.37802	0.29608	0.25574
		0.2548	0.1052	0.6072	0.7089	0.6819	0.1472	0.4078	0.0394	0.1121	0.1726
Test user documentation	18	-0.14192	-0.15521	0.1237	-0.0955	-0.01954	0.13768	-0.26364	0.03519	0.62667	0.4731
		0.4544	0.4128	0.5149	0.6157	0.9184	0.4681	0.1592	0.8535	0.0002	0.0083
Test user training	19	-0.16467	-0.09869	0.10366	-0.21074	0.01111	0.17436	-0.2483	0.06286	0.57278	0.48626
		0.3845	0.6039	0.5857	0.2636	0.9535	0.3568	0.1858	0.7414	0.0009	0.0064
Test product with users	20	-0.01822	0.09826	0.17465	-0.11657	-0.06635	0.22422	-0.4166	0.14604	0.5962	0.7262
		0.9239	0.6055	0.356	0.5396	0.7276	0.2336	0.022	0.4413	0.0005	0.0001
		1	2	3	4	5	6	7	8	9	10

Table 21 (Continued). HFE Correlation Matrix for Software Development Activity - Human Factors Engineer

Boxes with double-lined borders indicate p<= 0.0003.

Identify who the users will be	1										
Define each user identified	2										
Meet with the users	3										
Identify who the customers will be	4										
Define each customer	5										
Determine product requirements	6										
Define the market the product will be sold into	7										
Determine the feasibility of the product	8										
Consider design alternatives	9										
Determine the user interface design	10										
Determine the product design	11	1 0									
Develop the prototype	12	0.27277 0.1447	1 0								
Test the prototype	13	0.10336 0.5868	0.46013 0.0105	1 0							
Develop programs	14	0.06562 0.7305	0.40809 0.0252	0.18313 0.3327	1 0						
Develop user documentation	15	0.03795 0.8422	0.17887 0.3443	0.35773 0.0523	0.33367 0.0715	1 0					
Develop user training	16	0.04789 0.8016	0.18811 0.3195	0.41581 0.0223	0.34882 0.0589	0.94505 0.0001	1 0				
Test software	17	0.28583 0.1257	0.25517 0.1736	0.27396 0.1429	0.51749 0.0034	0.20905 0.2676	0.18169 0.3366	1 0			
Test user documentation	18	-0.09598 0.6139	0.15993 0.3985	0.58439 0.0007	0.39733 0.0297	0.51387 0.0037	0.51145 0.0039	0.30018 0.107	1 0		
Test user training	19	-0.08183 0.6673	0.2381 0.2052	0.58644 0.0007	0.48685 0.0064	0.49686 0.0052	0.5295 0.0026	0.33455 0.0708	0.94437 0.0001	1 0	
Test product with users	20	0.03621 0.8493	0.28446 0.1276	0.68867 0.0001	0.48947 0.006	0.46171 0.0102	0.51331 0.0037	0.33497 0.0704	0.65209 0.0001	0.71642 0.0001	1 0
		11	12	13	14	15	16	17	18	19	20

Table 22. HFE Correlation Matrix for Software Development Activity - Marketing Specialist

Boxes with double-lined borders indicate p<= 0.0003.

Identify who the users will be	1	1 0									
Define each user identified	2	0.72437 0.0001	1 0								
Meet with the users	3	0.34693 0.0603	0.35981 0.0508	1 0							
Identify who the customers will be	4	0.45746 0.011	0.18193 0.3359	0.22328 0.2356	1 0						
Define each customer	5	0.28884 0.1216	0.44114 0.0147	0.16402 0.3864	0.70872 0.0001	1 0					
Determine product requirements	6	0.23289 0.2155	0.33308 0.0721	0.33212 0.073	0.48571 0.0065	0.45794 0.0109	1 0				
Define the market the product will be sold into	7	0.62856 0.0002	0.34982 0.0581	0.27581 0.1401	0.6525 0.0001	0.53876 0.0021	0.33218 0.0729	1 0			
Determine the feasibility of the product	8	0.47585 0.0079	0.41265 0.0234	0.17196 0.3636	0.11676 0.5389	0.16794 0.375	0.40236 0.0275	0.28716 0.1239	1 0		
Consider design alternatives	9	0.23014 0.2211	0.20136 0.286	0.10812 0.5696	0.02259 0.9057	0.06034 0.7514	0.06325 0.7399	0.13131 0.4892	0.24851 0.1854	1 0	
Determine the user interface design	10	0.22022 0.2423	0.35311 0.0556	-0.00869 0.9636	0.03179 0.8676	0.09623 0.613	0.2225 0.2373	0.05543 0.7711	0.18185 0.3362	0.59806 0.0005	1 0
Determine the product design	11	0.29387 0.115	0.23764 0.206	0.01177 0.9508	0.01076 0.955	0.10925 0.5655	0.12054 0.5258	0.08133 0.6692	0.17524 0.3543	0.44073 0.0148	0.70735 0.0001
Develop the prototype	12	0.3534 0.0554	0.36527 0.0472	0.13552 0.4752	0.01239 0.9482	0.03309 0.8622	0.08671 0.6487	0.18002 0.3411	0.33254 0.0726	0.46615 0.0094	0.75242 0.0001
Test the prototype	13	0.34397 0.0627	0.34726 0.0601	0.25183 0.1794	0 1	0.01366 0.9429	0.05371 0.778	0.17841 0.3455	0.16883 0.3725	0.33968 0.0663	0.50987 0.004
Develop programs	14	0.29111 0.1186	0.37226 0.0428	0.25398 0.1756	-0.05714 0.7642	0.07632 0.6885	-0.04 0.8338	0.16609 0.3804	0.01257 0.9474	0.17393 0.358	0.48949 0.006
Develop user documentation	15	0.19952 0.2905	0.34829 0.0593	0.22595 0.2299	0.0306 0.8725	0.16892 0.3722	0.29985 0.1074	0.16008 0.3981	0.09426 0.6203	0.23705 0.2072	0.69574 0.0001
Develop user training	16	0.20086 0.2872	0.34576 0.0613	0.24367 0.1944	0.03791 0.8423	0.17216 0.363	0.22557 0.2307	0.15427 0.4157	0.04171 0.8268	0.16784 0.3753	0.60816 0.0004
Test software	17	0.3013 0.1057	0.35247 0.0561	0.30812 0.0976	0.0352 0.8535	0.13166 0.488	0.14786 0.4355	0.18419 0.3299	0.04648 0.8073	0.35068 0.0574	0.72742 0.0001
Test user documentation	18	0.17693 0.3496	0.32431 0.0804	0.41433 0.0228	0.12932 0.4958	0.21713 0.2491	0.40088 0.0281	0.20404 0.2795	0.05691 0.7652	0.32714 0.0776	0.50639 0.0043
Test user training	19	0.10279 0.5888	0.29463 0.114	0.4829 0.0069	0.14785 0.4356	0.24627 0.1896	0.41399 0.0229	0.20729 0.2717	0.01914 0.92	0.27916 0.1352	0.47952 0.0073
Test product with users	20	0.10084 0.596	0.10181 0.5924	0.20303 0.2819	0.19795 0.2944	0.1322 0.4862	0.17321 0.36	0.28768 0.1232	0.02178 0.9091	0.24648 0.1892	0.33399 0.0713
		1	2	3	4	5	6	7	8	9	10

Table 22 (Continued). HFE Correlation Matrix for Software Development Activity - Marketing Specialist

Boxes with double-lined borders indicate p<= 0.0003.

Identify who the users will be	1										
Define each user identified	2										
Meet with the users	3										
Identify who the customers will be	4										
Define each customer	5										
Determine product requirements	6										
Define the market the product will be sold into	7										
Determine the feasibility of the product	8										
Consider design alternatives	9										
Determine the user interface design	10										
Determine the product design	11	1 0									
Develop the prototype	12	0.51606 0.0035	1 0								
Test the prototype	13	0.38843 0.0339	0.74514 0.0001	1 0							
Develop programs	14	0.51228 0.0038	0.64166 0.0001	0.69821 0.0001	1 0						
Develop user documentation	15	0.59054 0.0006	0.57572 0.0009	0.59049 0.0006	0.64253 0.0001	1 0					
Develop user training	16	0.53578 0.0023	0.54075 0.002	0.62712 0.0002	0.72977 0.0001	0.96054 0.0001	1 0				
Test software	17	0.67948 0.0001	0.74789 0.0001	0.63531 0.0002	0.78858 0.0001	0.72836 0.0001	0.71282 0.0001	1 0			
Test user documentation	18	0.3663 0.0465	0.44852 0.0129	0.50701 0.0042	0.56899 0.001	0.54839 0.0017	0.52848 0.0027	0.69471 0.0001	1 0		
Test user training	19	0.33664 0.0689	0.46983 0.0088	0.52971 0.0026	0.60881 0.0004	0.55025 0.0016	0.55092 0.0016	0.72314 0.0001	0.94631 0.0001	1 0	
Test product with users	20	0.33926 0.0666	0.45056 0.0125	0.52715 0.0028	0.51962 0.0033	0.3957 0.0304	0.41367 0.0231	0.5122 0.0038	0.67194 0.0001	0.69596 0.0001	1 0
		11	12	13	14	15	16	17	18	19	20

Table 23. HFE Correlation Matrix for Software Development Activity - User Representatives

Boxes with double-lined borders indicate p<= 0.0003.

		1	2	3	4	5	6	7	8	9	10
Identify who the users will be	1	1 0									
Define each user identified	2	0.87351 0.0001	1 0								
Meet with the users	3	0.25946 0.1662	0.29411 0.1147	1 0							
Identify who the customers will be	4	0.35306 0.0556	0.21185 0.2611	0.49116 0.0058	1 0						
Define each customer	5	0.35392 0.055	0.37017 0.0441	0.37989 0.0384	0.66988 0.0001	1 0					
Determine product requirements	6	0.46903 0.0089	0.48849 0.0062	0.38759 0.0343	0.1635 0.388	0.1312 0.4895	1 0				
Define the market the product will be sold into	7	0.18165 0.3367	0.12846 0.4987	0.30093 0.1061	0.5145 0.0036	0.25787 0.1689	0.29443 0.1143	1 0			
Determine the feasibility of the product	8	0.04443 0.8157	-0.10926 0.5655	-0.15075 0.4265	0.12192 0.521	-0.01774 0.9259	0.24017 0.2011	0.49775 0.0051	1 0		
Consider design alternatives	9	0.24314 0.1954	0.01387 0.942	0.13485 0.4774	0.41708 0.0218	0.03702 0.846	0.3943 0.0311	0.48906 0.0061	0.46416 0.0098	1 0	
Determine the user interface design	10	0.36464 0.0476	0.21977 0.2432	0 1	-0.05379 0.7777	-0.25198 0.1792	0.47494 0.008	0.24908 0.1844	0.29701 0.111	0.50715 0.0042	1 0
Determine the product design	11	-0.19738 0.2958	-0.27172 0.1464	0.09497 0.6176	0.31807 0.0867	-0.01338 0.9441	0.15247 0.4212	0.65955 0.0001	0.46124 0.0103	0.55197 0.0016	0.30797 0.0978
Develop the prototype	12	-0.3314 0.0736	-0.41669 0.022	-0.05969 0.754	-0.05867 0.7581	-0.11901 0.5311	-0.31211 0.0931	0.16717 0.3773	0.11628 0.5406	0.06461 0.7345	-0.1573 0.4065
Test the prototype	13	-0.26255 0.161	-0.15881 0.4019	0.19618 0.2988	0.12253 0.5189	0.15101 0.4257	0.11502 0.545	0.11739 0.5367	-0.15912 0.401	-0.07819 0.6813	-0.29455 0.1141
Develop programs	14	-0.26425 0.1582	-0.29189 0.1176	0.03214 0.8661	-0.01701 0.9289	-0.0118 0.9506	-0.41302 0.0233	0.12252 0.5189	-0.06262 0.7424	-0.04752 0.8031	-0.3294 0.0755
Develop user documentation	15	0.11802 0.5345	0.0575 0.7628	0.24696 0.1883	0.0044 0.9816	-0.0351 0.8539	-0.12782 0.5009	0.12672 0.5046	-0.13948 0.4623	-0.09522 0.6167	0.17886 0.3443
Develop user training	16	0.14346 0.4495	0.06135 0.7474	0.28138 0.132	0.053 0.7809	-0.0705 0.7112	-0.11049 0.5611	0.16361 0.3876	-0.1113 0.5582	-0.05244 0.7832	0.20527 0.2765
Test software	17	-0.30477 0.1015	-0.35407 0.0549	0.31193 0.0933	-0.01699 0.929	-0.20047 0.2881	-0.06876 0.7181	0.01749 0.9269	-0.03849 0.84	0.00297 0.9876	0.05923 0.7559
Test user documentation	18	-0.16059 0.3966	-0.0826 0.6644	-0.10744 0.572	0.12003 0.5275	0.1381 0.4668	0.05578 0.7697	0.07801 0.682	-0.1932 0.3064	-0.10589 0.5776	-0.1101 0.5625
Test user training	19	-0.16059 0.3966	-0.0826 0.6644	-0.10744 0.572	0.12003 0.5275	0.1381 0.4668	0.05578 0.7697	0.07801 0.682	-0.1932 0.3064	-0.10589 0.5776	-0.1101 0.5625
Test product with users	20	-0.1289 0.4972	-0.08055 0.6722	-0.0749 0.694	0.17524 0.3543	0.18496 0.3278	-0.04298 0.8216	0.12773 0.5012	-0.15093 0.426	-0.07777 0.6829	-0.12726 0.5028
		1	2	3	4	5	6	7	8	9	10

Table 23 (Continued). HFE Correlation Matrix for Software Development Activity - User Representatives

Boxes with double-lined borders indicate p<= 0.0003.

		11	12	13	14	15	16	17	18	19	20
Identify who the users will be	1										
Define each user identified	2										
Meet with the users	3										
Identify who the customers will be	4										
Define each customer	5										
Determine product requirements	6										
Define the market the product will be sold into	7										
Determine the feasibility of the product	8										
Consider design alternatives	9										
Determine the user interface design	10										
Determine the product design	11	1 0									
Develop the prototype	12	0.08769 0.645	1 0								
Test the prototype	13	0.1642 0.3859	0.16337 0.3884	1 0							
Develop programs	14	-0.04722 0.8043	0.79588 0.0001	0.06727 0.7239	1 0						
Develop user documentation	15	-0.07173 0.7064	0.29438 0.1143	-0.09098 0.6325	0.41477 0.0227	1 0					
Develop user training	16	-0.05211 0.7845	0.31141 0.0939	-0.06181 0.7456	0.40029 0.0284	0.98043 0.0001	1 0				
Test software	17	0.34788 0.0596	0.13803 0.467	0.33601 0.0695	0.08325 0.6619	-0.06995 0.7134	-0.02702 0.8873	1 0			
Test user documentation	18	0.12495 0.5106	-0.0739 0.698	0.61115 0.0003	-0.09285 0.6256	-0.18605 0.3249	-0.22299 0.2362	0.23188 0.2176	1 0		
Test user training	19	0.12495 0.5106	-0.0739 0.698	0.61115 0.0003	-0.09285 0.6256	-0.18605 0.3249	-0.22299 0.2362	0.23188 0.2176	1 0.0001	1 0	
Test product with users	20	0.09374 0.6222	0.0688 0.7179	0.59531 0.0005	-0.01789 0.9253	-0.26128 0.1631	-0.24613 0.1898	0.27247 0.1452	0.85689 0.0001	0.85689 0.0001	1 0
		11	12	13	14	15	16	17	18	19	20

Table 24. Summary of HFE Correlation Matrices for Software Development Activities

Boxes with double-lined borders indicate $p <= 0.0003$ for at least five of the product team members

Activity	#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Identify who the users will be	1																				
Define each user identified	2	6																			
Meet with the users	3	1																			
Identify who the customers will be	4	1	1																		
Define each customer	5				5																
Determine product requirements	6																				
Define the market the product will be sold into	7	1			1	3															
Determine the feasibility of the product	8						1														
Consider design alternatives	9																				
Determine the user interface design	10									1											
Determine the product design	11							1	2	1	3										
Develop the prototype	12									1	3	3									
Test the prototype	13									1	2	2	4								
Develop programs	14									1	1	2	4	3							
Develop user documentation	15										1				1						
Develop user training	16	1	1											1	1	5					
Test software	17									1	1	2	2	3	1	1	1				
Test user documentation	18	1	1							1				1		2	1	1			
Test user training	19	1	1											1			2	2	7		
Test product with users	20										1			2					6	6	

Table 25. SD Correlation Matrix for Software Development Activity - Overall

Boxes with double-lined borders indicate p<= 0.0003.

Identify who the users will be	1	1 0									
Define each user identified	2	0.14634 0.4403	1 0								
Meet with the users	3	0.03287 0.8631	0.05503 0.7727	1 0							
Identify who the customers will be	4	0.0886 0.6415	-0.1281 0.4999	0.02271 0.9052	1 0						
Define each customer	5	0.02303 0.9038	0.25414 0.1753	0.18699 0.3224	0.34486 0.062	1 0					
Determine product requirements	6	0.09775 0.6073	-0.02604 0.8914	-0.04595 0.8095	-0.03378 0.8594	-0.19025 0.3139	1 0				
Define the market the product will be sold into	7	0.22661 0.2285	0.0845 0.6571	0.09102 0.6324	0.68381 0.0001	0.25105 0.1808	0.12383 0.5144	1 0			
Determine the feasibility of the product	8	0.3755 0.0409	0.08133 0.6692	0.06418 0.7362	0.01996 0.9166	0.00865 0.9638	0.28998 0.1201	0.2842 0.128	1 0		
Consider design alternatives	9	0.45392 0.0117	-0.13817 0.4665	0 1	0.20912 0.2674	0.3262 0.0785	-0.11537 0.5438	0.37442 0.0415	0.47725 0.0077	1 0	
Determine the user interface design	10	0.21679 0.2499	0.10134 0.5941	0.15615 0.4099	0.40663 0.0258	0.23183 0.2177	0.122 0.5207	0.31567 0.0893	0.34655 0.0606	0.2924 0.1169	1 0
Determine the product design	11	0.12388 0.5143	0.1579 0.4046	0.14821 0.4344	0.23542 0.2104	0.28747 0.1235	0.19285 0.3073	0.08576 0.6523	0.30468 0.1016	0.0731 0.7011	0.37157 0.0432
Develop the prototype	12	0.14484 0.4451	-0.05511 0.7724	0.06189 0.7453	0 1	0.17348 0.3593	0.09203 0.6286	0.04267 0.8229	0.21755 0.2482	0.17094 0.3664	-0.11663 0.5394
Test the prototype	13	0.4475 0.0132	-0.16582 0.3812	-0.29264 0.1166	0.05378 0.7777	-0.05826 0.7598	-0.00989 0.9586	0.16966 0.3701	0.09352 0.6231	0.13778 0.4678	-0.11593 0.5418
Develop programs	14	0.27235 0.1454	0.20725 0.2718	-0.11638 0.5403	0.13941 0.4625	0.05437 0.7754	0.11537 0.5438	0.16046 0.397	0.34089 0.0653	0.35714 0.0527	0.2193 0.2443
Develop user documentation	15	0.30855 0.0971	-0.03287 0.8631	0.17931 0.3431	0.24165 0.1983	0.09239 0.6273	0.08626 0.6504	0.26541 0.1563	0.2966 0.1115	0.36415 0.0479	0.15404 0.4164
Develop user training	16	0.18605 0.3249	0.04719 0.8044	0.159 0.4013	0.42857 0.0181	0.37139 0.0433	0.07881 0.6789	0.58463 0.0007	0.09315 0.6244	0.39036 0.033	0.04994 0.7933
Test software	17	0.52105 0.0032	0.0793 0.677	-0.23378 0.2137	0.26005 0.1652	0.15602 0.4103	0.26486 0.1572	0.21489 0.2541	0.13696 0.4705	0.30747 0.0984	0.3776 0.0397
Test user documentation	18	0.13642 0.4722	-0.09343 0.6234	0.06412 0.7364	0.49232 0.0057	0.16339 0.3883	0.20803 0.27	0.49029 0.006	-0.07172 0.7065	0.21467 0.2546	0.13182 0.4875
Test user training	19	0.23066 0.2201	-0.13603 0.4735	0.05914 0.7562	0.50033 0.0049	0.39712 0.0298	0.24182 0.1979	0.50622 0.0043	-0.0563 0.7676	0.31759 0.0872	0.1068 0.5743
Test product with users	20	-0.16827 0.3741	-0.04482 0.8141	0.38827 0.034	0.20027 0.2886	0.02519 0.8949	0.01069 0.9553	-0.13384 0.4807	-0.13269 0.4846	-0.19859 0.2928	-0.06097 0.7489
		1	2	3	4	5	6	7	8	9	10

Table 25 (Continued). SD Correlation Matrix for Software Development Activity - Overall

Boxes with double-lined borders indicate p<= 0.0003.

Identify who the users will be	1										
Define each user identified	2										
Meet with the users	3										
Identify who the customers will be	4										
Define each customer	5										
Determine product requirements	6										
Define the market the product will be sold into	7										
Determine the feasibility of the product	8										
Consider design alternatives	9										
Determine the user interface design	10										
Determine the product design	11	1 0									
Develop the prototype	12	0.29157 0.118	1 0								
Test the prototype	13	-0.18174 0.3365	0.40299 0.0272	1 0							
Develop programs	14	0.36551 0.047	0.2849 0.127	0.13778 0.4678	1 0						
Develop user documentation	15	0.01988 0.917	0.17429 0.357	0.03434 0.857	0.29132 0.1183	1 0					
Develop user training	16	0.09988 0.5995	0.27247 0.1452	0.15686 0.4078	0.29277 0.1164	0.59702 0.0005	1 0				
Test software	17	0.25174 0.1796	0.08176 0.6676	0.17133 0.3653	0.10249 0.5899	-0.0836 0.6605	-0.07001 0.7131	1 0			
Test user documentation	18	0.03295 0.8627	0.08562 0.6528	0.04831 0.7999	-0.161 0.3954	0.26265 0.1608	0.40328 0.0271	0.24642 0.1893	1 0		
Test user training	19	0.07894 0.6784	0.28954 0.1207	0.16919 0.3714	0.18148 0.3372	0.35158 0.0568	0.68186 0.0001	0.15624 0.4097	0.66814 0.0001	1 0	
Test product with users	20	0.06097 0.7489	0.15842 0.4031	-0.18727 0.3217	-0.0662 0.7282	0.21599 0.2517	-0.04522 0.8124	-0.20897 0.2678	0.30837 0.0973	0.24808 0.1862	1 0
		11	12	13	14	15	16	17	18	19	20

Table 26. SD Correlation Matrix for Software Development Activity - Programmer

Boxes with double-lined borders indicate p<= 0.0003.

Identify who the users will be	1	1 0									
Define each user identified	2	0.77318 0.0001	1 0								
Meet with the users	3	0.12741 0.5023	-0.01063 0.9555	1 0							
Identify who the customers will be	4	0.47525 0.008	0.28591 0.1256	0.25925 0.1665	1 0						
Define each customer	5	0.28966 0.1205	0.33195 0.0731	0.27194 0.146	0.51244 0.0038	1 0					
Determine product requirements	6	0.5609 0.0013	0.55394 0.0015	0.01202 0.9497	0.40387 0.0269	0.15387 0.4169	1 0				
Define the market the product will be sold into	7	0.19399 0.3043	0.1065 0.5754	0.0893 0.6389	0.58673 0.0007	0.44877 0.0129	0.41791 0.0216	1 0			
Determine the feasibility of the product	8	-0.28 0.134	-0.29366 0.1152	-0.12685 0.5042	0.00868 0.9637	0.10624 0.5763	-0.01006 0.9579	-0.01246 0.9479	1 0		
Consider design alternatives	9	-0.15953 0.3997	-0.25287 0.1776	-0.06324 0.7399	0.13994 0.4608	-0.02774 0.8843	0.0719 0.7058	0.34786 0.0596	0.49412 0.0055	1 0	
Determine the user interface design	10	0.50087 0.0048	0.34996 0.058	0.22336 0.2354	0.4637 0.0099	0.24053 0.2004	0.43702 0.0157	0.35836 0.0518	-0.11427 0.5477	-0.07251 0.7034	1 0
Determine the product design	11	0.07687 0.6864	0 1	0.02438 0.8983	0.27527 0.1409	0.34999 0.058	0.34803 0.0595	0.28733 0.1237	0.12754 0.5018	0.10174 0.5927	0.23956 0.2023
Develop the prototype	12	0.114 0.5486	0.14673 0.4391	-0.1162 0.5409	0.20411 0.2793	0.20391 0.2798	0.11674 0.539	0.18262 0.3341	-0.14592 0.4417	-0.07544 0.692	0.19984 0.2897
Test the prototype	13	0.09988 0.5995	0.11175 0.5566	0.11179 0.5565	0.14536 0.4434	0.17388 0.3581	0.17512 0.3547	0.14824 0.4343	-0.19887 0.2921	-0.02722 0.8865	0.29525 0.1132
Develop programs	14	-0.41726 0.0218	-0.35346 0.0554	0 1	-0.27691 0.1385	-0.23749 0.2064	-0.28459 0.1274	-0.31494 0.09	-0.04793 0.8014	-0.04248 0.8236	-0.07502 0.6936
Develop user documentation	15	-0.01045 0.9563	-0.08632 0.6502	0.18642 0.324	0.33427 0.071	0.47733 0.0076	-0.03253 0.8645	0.41751 0.0217	0.09884 0.6033	0.06743 0.7233	0.5313 0.0025
Develop user training	16	-0.01457 0.9391	0.06806 0.7208	0.11549 0.5434	0.26242 0.1612	0.51681 0.0035	0.03481 0.8551	0.32672 0.078	-0.21271 0.2591	-0.2153 0.2532	0.41427 0.0228
Test software	17	0.0055 0.977	0.03858 0.8396	0.10474 0.5818	-0.03046 0.873	-0.04386 0.818	0.04569 0.8105	-0.00772 0.9677	-0.14797 0.4352	0.16028 0.3975	0.31523 0.0897
Test user documentation	18	0.03701 0.846	0.13585 0.4741	-0.02934 0.8777	0.25704 0.1703	0.30192 0.1049	0.07447 0.6957	0.51014 0.004	-0.25792 0.1688	0.07756 0.6837	0.31719 0.0877
Test user training	19	0.06099 0.7488	0.06106 0.7486	0.05803 0.7607	0.35742 0.0525	0.31243 0.0928	0 1	0.47024 0.0087	-0.30362 0.1029	-0.06054 0.7506	0.35642 0.0532
Test product with users	20	-0.01823 0.9238	0.08899 0.64	0.09758 0.608	-0.0883 0.6426	-0.06875 0.7181	0.11954 0.5292	0.18531 0.3269	-0.44022 0.0149	-0.14631 0.4404	0.39424 0.0311
		1	2	3	4	5	6	7	8	9	10

Table 26 (Continued). SD Correlation Matrix for Software Development Activity - Programmer

Boxes with double-lined borders indicate p<= 0.0003.

		11	12	13	14	15	16	17	18	19	20
Identify who the users will be	1										
Define each user identified	2										
Meet with the users	3										
Identify who the customers will be	4										
Define each customer	5										
Determine product requirements	6										
Define the market the product will be sold into	7										
Determine the feasibility of the product	8										
Consider design alternatives	9										
Determine the user interface design	10										
Determine the product design	11	1 0									
Develop the prototype	12	0.18693 0.3226	1 0								
Test the prototype	13	0.40464 0.0266	0.78941 0.0001	1 0							
Develop programs	14	-0.18422 0.3298	0.01951 0.9185	0.21824 0.2466	1 0						
Develop user documentation	15	0.38988 0.0332	-0.01906 0.9204	0.16504 0.3834	-0.03757 0.8437	1 0					
Develop user training	16	0.30657 0.0994	0.29818 0.1095	0.28331 0.1292	-0.08146 0.6687	0.67635 0.0001	1 0				
Test software	17	0.22115 0.2402	0.27777 0.1372	0.62542 0.0002	0.38257 0.0369	0.14175 0.455	0.00798 0.9666	1 0			
Test user documentation	18	0.31862 0.0861	0.21751 0.2482	0.40318 0.0272	-0.16261 0.3906	0.41153 0.0239	0.43387 0.0166	0.38536 0.0355	1 0		
Test user training	19	0.24505 0.1918	0.33375 0.0715	0.44149 0.0146	0 1	0.46405 0.0098	0.66343 0.0001	0.30083 0.1062	0.80061 0.0001	1 0	
Test product with users	20	-0.10465 0.5821	0.11917 0.5305	0.26796 0.1522	0.20757 0.271	0.21076 0.2636	0.37022 0.044	0.17237 0.3624	0.48709 0.0063	0.46711 0.0093	1 0

Table 27. SD Correlation Matrix for Software Development Activity - Technical Writer

Boxes with double-lined borders indicate p<= 0.0003.

		1	2	3	4	5	6	7	8	9	10
Identify who the users will be	1	1									
		0									
Define each user identified	2	0.76773	1								
		0.0001	0								
Meet with the users	3	0.44882	0.53631	1							
		0.0129	0.0023	0							
Identify who the customers will be	4	0.42982	0.32774	0.13799	1						
		0.0178	0.0771	0.4671	0						
Define each customer	5	0.21356	0.21114	0.06736	0.74968	1					
		0.2571	0.2627	0.7236	0.0001	0					
Determine product requirements	6	0.25083	0.22515	0.3417	0.50112	0.56639	1				
		0.1812	0.2316	0.0646	0.0048	0.0011	0				
Define the market the product will be sold into	7	0.50903	0.29373	0.28818	0.64614	0.62417	0.59828	1			
		0.0041	0.1152	0.1225	0.0001	0.0002	0.0005	0			
Determine the feasibility of the product	8	0.28821	0.11603	0.30047	0.34486	0.12174	0.2428	0.18571	1		
		0.1225	0.5415	0.1067	0.062	0.5216	0.1961	0.3258	0		
Consider design alternatives	9	0.14167	0.04542	0.40994	0.14477	0.01817	0.34536	0.30037	0.54688	1	
		0.4552	0.8116	0.0245	0.4453	0.9241	0.0616	0.1068	0.0018	0	
Determine the user interface design	10	0.31998	0.32638	0.56358	0.08453	-0.10444	0.26592	0.34949	0.19171	0.45773	1
		0.0847	0.0784	0.0012	0.657	0.5828	0.1555	0.0583	0.3102	0.011	0
Determine the product design	11	0.26573	0.1655	0.23402	0.35397	0.19958	0.26	0.36793	0.55041	0.47788	0.51514
		0.1558	0.3821	0.2133	0.055	0.2903	0.1653	0.0455	0.0016	0.0076	0.0036
Develop the prototype	12	0.3569	0.11894	0.29549	0.38027	0.24554	0.25528	0.43499	0.74932	0.49771	0.41568
		0.0529	0.5313	0.1129	0.0382	0.1909	0.1734	0.0163	0.0001	0.0051	0.0223
Test the prototype	13	0.1944	-0.04774	0.21158	0.10167	0.08066	0.25483	0.34217	0.50281	0.43865	0.38989
		0.3033	0.8022	0.2617	0.5929	0.6718	0.1741	0.0642	0.0046	0.0153	0.0332
Develop programs	14	0.30818	-0.04012	0.15745	0.23559	0.15626	0.12617	0.35579	0.58297	0.43682	0.20218
		0.0976	0.8333	0.406	0.2101	0.4096	0.5065	0.0537	0.0007	0.0158	0.284
Develop user documentation	15	0.02106	0.0189	0.06491	0.17889	0.07561	0.10268	0.13395	-0.05552	0.16569	0.19052
		0.912	0.921	0.7333	0.3442	0.6913	0.5893	0.4804	0.7708	0.3815	0.3132
Develop user training	16	-0.0016	0.06319	0.59745	0.06152	0.03734	0.24573	0.10855	0.2573	0.28199	0.35463
		0.9933	0.7401	0.0005	0.7467	0.8447	0.1906	0.568	0.1699	0.1311	0.0545
Test software	17	0.20092	0.11933	0.44966	0.01486	0.02983	0.11416	0.30107	0.33652	0.31853	0.34166
		0.2871	0.53	0.0127	0.9379	0.8757	0.5481	0.1059	0.069	0.0862	0.0646
Test user documentation	18	0.50035	0.56836	0.28466	0.18212	0.12718	0.06476	0.16272	-0.09338	0.02787	0.08012
		0.0049	0.0011	0.1273	0.3354	0.503	0.7338	0.3903	0.6236	0.8838	0.6739
Test user training	19	0.18043	0.14396	0.61795	0.01793	0.07198	0.22807	0.30226	0.26426	0.42904	0.47156
		0.34	0.4479	0.0003	0.9251	0.7054	0.2254	0.1045	0.1582	0.018	0.0085
Test product with users	20	0.28718	0.17261	0.5593	0.1742	0.11129	0.18196	0.32008	0.19344	0.2588	0.38341
		0.1239	0.3617	0.0013	0.3572	0.5582	0.3359	0.0846	0.3057	0.1673	0.0365
		1	2	3	4	5	6	7	8	9	10

Table 27 (Continued). SD Correlation Matrix for Software Development Activity - Technical Writer

Boxes with double-lined borders indicate $p <= 0.0003$.

		11	12	13	14	15	16	17	18	19	20
Identify who the users will be	1										
Define each user identified	2										
Meet with the users	3										
Identify who the customers will be	4										
Define each customer	5										
Determine product requirements	6										
Define the market the product will be sold into	7										
Determine the feasibility of the product	8										
Consider design alternatives	9										
Determine the user interface design	10										
Determine the product design	11	1 0									
Develop the prototype	12	0.78577 0.0001	1 0								
Test the prototype	13	0.72379 0.0001	0.75818 0.0001	1 0							
Develop programs	14	0.69037 0.0001	0.80056 0.0001	0.58502 0.0007	1 0						
Develop user documentation	15	0.14207 0.4539	0.09798 0.6065	0.13213 0.4864	0.13097 0.4903	1 0					
Develop user training	16	0.1781 0.3464	0.16803 0.3748	0.16792 0.3751	0.19198 0.3095	-0.11527 0.5441	1 0				
Test software	17	0.56562 0.0011	0.49801 0.0051	0.62726 0.0002	0.44541 0.0136	0.00495 0.9793	0.42246 0.02	1 0			
Test user documentation	18	0.01494 0.9376	-0.18835 0.3189	-0.08082 0.6712	-0.07127 0.7082	-0.058 0.7608	0.20271 0.2827	0.00832 0.9652	1 0		
Test user training	19	0.33813 0.0676	0.2665 0.1546	0.2973 0.1106	0.32269 0.082	-0.26261 0.1609	0.79809 0.0001	0.5463 0.0018	0.27608 0.1397	1 0	
Test product with users	20	0.29445 0.1142	0.28926 0.1211	0.27564 0.1404	0.26565 0.156	-0.00414 0.9827	0.76047 0.0001	0.53552 0.0023	0.20209 0.2842	0.75724 0.0001	1 0

Table 28. SD Correlation Matrix for Software Development Activity - Training Developer

Boxes with double-lined borders indicate p<= 0.0003.

Identify who the users will be	1	1 0									
Define each user identified	2	0.82736 0.0001	1 0								
Meet with the users	3	0.31118 0.0942	0.38104 0.0378	1 0							
Identify who the customers will be	4	0.46848 0.009	0.45724 0.0111	0.32279 0.0819	1 0						
Define each customer	5	0.35377 0.0551	0.41953 0.021	0.40829 0.0251	0.84637 0.0001	1 0					
Determine product requirements	6	0.18188 0.3361	0.15478 0.4141	-0.06323 0.7399	0.45175 0.0122	0.52679 0.0028	1 0				
Define the market the product will be sold into	7	0.35413 0.0549	0.24396 0.1939	0.19346 0.3057	0.50261 0.0046	0.53955 0.0021	0.67205 0.0001	1 0			
Determine the feasibility of the product	8	0.24022 0.201	0.16737 0.3767	0.12668 0.5047	0.2586 0.1676	0.36006 0.0507	0.63468 0.0002	0.5212 0.0031	1 0		
Consider design alternatives	9	0.19897 0.2918	0.07091 0.7096	-0.12269 0.5184	0.27281 0.1447	0.19926 0.2911	0.54149 0.002	0.33786 0.0678	0.72991 0.0001	1 0	
Determine the user interface design	10	0.3204 0.0843	0.15626 0.4096	0.1219 0.5211	0.08993 0.6365	0.07032 0.7119	0.39705 0.0298	0.39411 0.0312	0.42171 0.0203	0.37517 0.0411	1 0
Determine the product design	11	0.21499 0.2539	0.04331 0.8202	0.01873 0.9217	0.03005 0.8748	0.00761 0.9682	0.35305 0.0557	0.29336 0.1156	0.36967 0.0444	0.43962 0.0151	0.67142 0.0001
Develop the prototype	12	0.34195 0.0644	0.19012 0.3143	0.13118 0.4896	0.32174 0.083	0.26989 0.1492	0.61796 0.0003	0.39197 0.0322	0.65229 0.0001	0.75499 0.0001	0.45941 0.0107
Test the prototype	13	0.08114 0.6699	0.0537 0.7781	0.0813 0.6693	-0.02202 0.9081	-0.04952 0.795	0.2854 0.1263	0.03622 0.8493	0.2292 0.2231	0.41457 0.0227	0.54038 0.0021
Develop programs	14	0.25983 0.1656	0.11179 0.5565	0.10414 0.5839	0.25245 0.1783	0.20085 0.2872	0.44099 0.0147	0.28333 0.1292	0.37778 0.0396	0.5232 0.003	0.43736 0.0157
Develop user documentation	15	0.50449 0.0045	0.43826 0.0154	0.41523 0.0225	0.16584 0.3811	0.05559 0.7705	0.0804 0.6728	0.30608 0.1	0.1467 0.4392	0.09768 0.6076	0.45981 0.0106
Develop user training	16	0.06122 0.7479	0.08104 0.6703	0.16651 0.3792	0.28623 0.1252	0.23662 0.2081	0.19025 0.3139	0.19132 0.3112	0.14242 0.4528	0.12069 0.5252	0.14722 0.4376
Test software	17	0.38464 0.0358	0.2364 0.2085	-0.13371 0.4812	-0.10838 0.5686	-0.15276 0.4203	0.31962 0.0851	0.16076 0.3961	0.28761 0.1233	0.41008 0.0244	0.45607 0.0113
Test user documentation	18	0.66516 0.0001	0.52443 0.0029	0.33885 0.067	0.25867 0.1675	0.30245 0.1043	0.2198 0.2432	0.26406 0.1585	0.18204 0.3356	0.15427 0.4157	0.34751 0.0599
Test user training	19	0.61222 0.0003	0.68887 0.0001	-0.0964 0.6123	0.28623 0.1252	0.23662 0.2081	0.19025 0.3139	0.19132 0.3112	0.14242 0.4528	0.12069 0.5252	0.28969 0.1205
Test product with users	20	0.51726 0.0034	0.54208 0.002	0.34245 0.064	0.38731 0.0345	0.26744 0.1531	0.11334 0.5509	0.17626 0.3515	0.11281 0.5528	0.10925 0.5655	0.24074 0.2
		1	2	3	4	5	6	7	8	9	10

Table 28 (Continued). SD Correlation Matrix for Software Development Activity - Training Developer

Boxes with double-lined borders indicate p<= 0.0003.

		11	12	13	14	15	16	17	18	19	20
Identify who the users will be	1										
Define each user identified	2										
Meet with the users	3										
Identify who the customers will be	4										
Define each customer	5										
Determine product requirements	6										
Define the market the product will be sold into	7										
Determine the feasibility of the product	8										
Consider design alternatives	9										
Determine the user interface design	10										
Determine the product design	11	1 0									
Develop the prototype	12	0.55519 0.0014	1 0								
Test the prototype	13	0.66189 0.0001	0.63741 0.0002	1 0							
Develop programs	14	0.43126 0.0173	0.83049 0.0001	0.52092 0.0032	1 0						
Develop user documentation	15	0.35792 0.0521	0.30154 0.1054	0.30934 0.0962	0.40701 0.0256	1 0					
Develop user training	16	0.02106 0.912	0.13097 0.4903	0.18933 0.3163	0.11708 0.5378	0.03552 0.8522	1 0				
Test software	17	0.43946 0.0151	0.4771 0.0077	0.45706 0.0111	0.34151 0.0647	0.19659 0.2978	-0.21664 0.2502	1 0			
Test user documentation	18	0.27928 0.135	0.24126 0.199	0.11683 0.5387	0.28995 0.1201	0.55615 0.0014	-0.20936 0.2668	0.29175 0.1177	1 0		
Test user training	19	0.17901 0.3439	0.13097 0.4903	0.18933 0.3163	0.11708 0.5378	0.3907 0.0328	-0.03448 0.8564	0.24759 0.1871	0.45178 0.0122	1 0	
Test product with users	20	0.37254 0.0426	0.25222 0.1787	0.28959 0.1206	0.25503 0.1738	0.58143 0.0008	-0.10925 0.5655	0.10351 0.5862	0.47131 0.0086	0.6191 0.0003	1 0

Table 29. SD Correlation Matrix for Software Development Activity - Human Factors Engineer

Boxes with double-lined borders indicate p<= 0.0003.

Identify who the users will be	1	1 0									
Define each user identified	2	0.87465 0.0001	1 0								
Meet with the users	3	0.62886 0.0002	0.59008 0.0006	1 0							
Identify who the customers will be	4	0.48413 0.0067	0.50383 0.0045	0.37303 0.0423	1 0						
Define each customer	5	0.25775 0.1691	0.37235 0.0427	0.24499 0.1919	0.76472 0.0001	1 0					
Determine product requirements	6	0.39051 0.0329	0.31843 0.0864	0.32096 0.0837	0.30519 0.101	0.24878 0.1849	1 0				
Define the market the product will be sold into	7	0.17024 0.3684	0.18445 0.3292	0.11047 0.5611	0.68283 0.0001	0.65305 0.0001	0.16403 0.3864	1 0			
Determine the feasibility of the product	8	0.26729 0.1533	0.20065 0.2877	0.11661 0.5394	0.35358 0.0553	0.13144 0.4887	0.36264 0.0489	0.23845 0.2045	1 0		
Consider design alternatives	9	0.20987 0.2656	0.07587 0.6903	0.12973 0.4945	0.39489 0.0308	0.16778 0.3755	0.60164 0.0004	0.25289 0.1776	0.43697 0.0158	1 0	
Determine the user interface design	10	0.01605 0.9329	0.01506 0.937	-0.03251 0.8646	-0.21857 0.2459	-0.20391 0.2798	0.31154 0.0938	-0.15098 0.4258	0.35557 0.0538	0.20291 0.2822	1 0
Determine the product design	11	0.18711 0.3221	0.17557 0.3534	0.14992 0.4291	0.0624 0.7432	0 1	0.70514 0.0001	-0.01037 0.9566	0.47368 0.0082	0.33535 0.07	0.35557 0.0538
Develop the prototype	12	0.01376 0.9425	-0.0113 0.9527	0.37417 0.0417	0.27441 0.1422	0.12125 0.5233	0.32546 0.0793	0.26089 0.1638	0.27437 0.1423	0.47809 0.0075	0.19375 0.3049
Test the prototype	13	0.38204 0.0372	0.35848 0.0517	0.28985 0.1203	0.49761 0.0051	0.35396 0.055	0.49454 0.0055	0.35435 0.0547	0.27474 0.1417	0.48626 0.0064	0.36827 0.0452
Develop programs	14	0.12606 0.5068	0.04278 0.8224	0.3527 0.0559	0.27131 0.147	0.16267 0.3904	0.48317 0.0068	0.30065 0.1064	0.52284 0.003	0.51903 0.0033	0.17364 0.3588
Develop user documentation	15	0.52407 0.003	0.61938 0.0003	0.51083 0.0039	0.07055 0.711	0.06391 0.7372	0.36631 0.0465	-0.03657 0.8478	0.02142 0.9105	-0.04274 0.8225	-0.10292 0.5884
Develop user training	16	0.52067 0.0032	0.54366 0.0019	0.45502 0.0115	0.15231 0.4217	0.0754 0.6921	0.48982 0.006	0.07364 0.6989	0.19657 0.2978	0.10195 0.5919	-0.07117 0.7086
Test software	17	0.18963 0.3156	0.1229 0.5176	0.03168 0.868	0.14451 0.4461	0.07851 0.6801	0.53635 0.0022	0.1926 0.3079	0.43883 0.0153	0.4712 0.0086	0.32593 0.0788
Test user documentation	18	0.50452 0.0045	0.52468 0.0029	0.4722 0.0084	0.13464 0.4781	0.00597 0.975	0.29379 0.1151	-0.11727 0.5371	0.19366 0.3052	-0.018 0.9248	0.01292 0.946
Test user training	19	0.37389 0.0418	0.43056 0.0175	0.39894 0.029	0.13224 0.4861	0.24143 0.1987	0.28608 0.1254	0.01538 0.9357	0.16732 0.3768	-0.13568 0.4747	-0.00502 0.979
Test product with users	20	0.1274 0.5023	0.14592 0.4417	0.05722 0.7639	0.16766 0.3758	0.15509 0.4132	0.58748 0.0006	0.24054 0.2004	0.16602 0.3806	0.43522 0.0162	0.11133 0.5581
		1	2	3	4	5	6	7	8	9	10

Table 29 (Continued). SD Correlation Matrix for Software Development Activity - Human Factors Engineer

Boxes with double-lined borders indicate p<= 0.0003.

		11	12	13	14	15	16	17	18	19	20
Identify who the users will be	1										
Define each user identified	2										
Meet with the users	3										
Identify who the customers will be	4										
Define each customer	5										
Determine product requirements	6										
Define the market the product will be sold into	7										
Determine the feasibility of the product	8										
Consider design alternatives	9										
Determine the user interface design	10										
Determine the product design	11	1 0									
Develop the prototype	12	0.41664 0.022	1 0								
Test the prototype	13	0.43173 0.0172	0.58098 0.0008	1 0							
Develop programs	14	0.58622 0.0007	0.80658 0.0001	0.49229 0.0057	1 0						
Develop user documentation	15	0.19282 0.3073	-0.04688 0.8057	-0.11317 0.5516	0.15908 0.4011	1 0					
Develop user training	16	0.26594 0.1555	0.03944 0.8361	-0.07185 0.7059	0.22857 0.2244	0.89741 0.0001	1 0				
Test software	17	0.64669 0.0001	0.43553 0.0161	0.65305 0.0001	0.56085 0.0013	0.05328 0.7798	0.12008 0.5273	1 0			
Test user documentation	18	0.40885 0.0249	-0.07201 0.7053	0.08692 0.6479	0.16626 0.3799	0.61898 0.0003	0.49007 0.006	0.19987 0.2896	1 0		
Test user training	19	0.32348 0.0812	-0.16584 0.3811	-0.08318 0.6621	0.12424 0.513	0.55395 0.0015	0.49256 0.0057	0.00489 0.9795	0.71144 0.0001	1 0	
Test product with users	20	0.49805 0.0051	0.02066 0.9137	0.11692 0.5383	0.11217 0.5551	0.1742 0.3572	0.26179 0.1623	0.30436 0.102	0.19307 0.3067	0.35889 0.0515	1 0
		11	12	13	14	15	16	17	18	19	20

Table 30. SD Correlation Matrix for Software Development Activity - Marketing Specialist

Boxes with double-lined borders indicate p<= 0.0003.

Activity		1	2	3	4	5	6	7	8	9	10
Identify who the users will be	1	1 0									
Define each user identified	2	0.96563 0.0001	1 0								
Meet with the users	3	0.72583 0.0001	0.66716 0.0001	1 0							
Identify who the customers will be	4	-0.14457 0.4459	-0.17405 0.3576	-0.25822 0.1683	1 0						
Define each customer	5	0.38938 0.0334	0.38639 0.0349	0.22986 0.2217	-0.175 0.355	1 0					
Determine product requirements	6	0.30476 0.1015	0.26719 0.1535	0.32454 0.0802	0.16496 0.3837	0.14863 0.4331	1 0				
Define the market the product will be sold into	7	0.02819 0.8825	0.01074 0.9551	-0.13793 0.4673	0.13441 0.4788	-0.07754 0.6838	0.2201 0.2425	1 0			
Determine the feasibility of the product	8	0.19957 0.2904	0.19009 0.3144	-0.05549 0.7709	-0.11384 0.5492	0.10695 0.5738	0.20238 0.2835	0 1	1 0		
Consider design alternatives	9	0.1851 0.3275	0.1287 0.4979	0.21512 0.2536	-0.00929 0.9611	-0.08366 0.6603	0.48081 0.0072	0.01132 0.9526	0.45546 0.0114	1 0	
Determine the user interface design	10	0.45986 0.0106	0.41956 0.021	0.53296 0.0024	-0.0486 0.7987	0.08561 0.6529	0.35484 0.0543	-0.23687 0.2076	0.23822 0.2049	0.63677 0.0002	1 0
Determine the product design	11	0.29767 0.1101	0.22375 0.2346	0.39244 0.0319	-0.28874 0.1218	-0.09801 0.6064	0.29743 0.1104	-0.27557 0.1405	0.4751 0.008	0.79332 0.0001	0.74789 0.0001
Develop the prototype	12	0.0623 0.7437	0.01483 0.938	0.05954 0.7546	0.15635 0.4093	-0.0612 0.748	0.35986 0.0508	0.09526 0.6166	0.30657 0.0994	0.53172 0.0025	0.36808 0.0454
Test the prototype	13	0.07777 0.6829	0.00539 0.9775	0.12541 0.5091	0.09404 0.6211	0.00278 0.9884	0.2625 0.1611	-0.40649 0.0258	0.30617 0.0999	0.51683 0.0035	0.47528 0.0079
Develop programs	14	0.0623 0.7437	0.01483 0.938	0.05954 0.7546	0.15635 0.4093	-0.0612 0.748	0.35986 0.0508	0.09526 0.6166	0.30657 0.0994	0.53172 0.0025	0.36808 0.0454
Develop user documentation	15	0.09073 0.6335	0.08946 0.6383	0.07508 0.6933	-0.06563 0.7304	0.14052 0.4589	0.11141 0.5578	-0.18933 0.3163	0.21011 0.2651	0.64095 0.0001	0.52135 0.0031
Develop user training	16	0.06475 0.7339	0.04485 0.8139	0.018 0.9248	0.22899 0.2235	0.05783 0.7615	0.39866 0.0291	-0.25203 0.1791	0.34762 0.0598	0.68566 0.0001	0.46374 0.0098
Test software	17	0.23509 0.2111	0.1773 0.3486	0.20983 0.2658	-0.34559 0.0614	0.02074 0.9134	0.21637 0.2508	-0.04108 0.8293	0.26444 0.1579	0.44709 0.0132	0.65012 0.0001
Test user documentation	18	0.17726 0.3487	0.1013 0.5943	0.24395 0.1939	-0.13346 0.482	0.13932 0.4628	0.22598 0.2298	-0.21685 0.2497	0.39546 0.0305	0.49839 0.0051	0.55859 0.0013
Test user training	19	0.04359 0.8191	-0.05813 0.7603	0.17165 0.3644	0.17505 0.3548	0.09851 0.6045	0.34561 0.0614	-0.21331 0.2577	0.27889 0.1356	0.39835 0.0292	0.33771 0.068
Test product with users	20	0.16862 0.3731	0.13277 0.4843	0.37474 0.0413	0.02539 0.894	-0.0751 0.6933	0.21318 0.258	-0.15127 0.4249	0.26555 0.1561	0.56893 0.001	0.49595 0.0053
		1	2	3	4	5	6	7	8	9	10

Table 30 (Continued). SD Correlation Matrix for Software Development Activity - Marketing Specialist

Boxes with double-lined borders indicate p<= 0.0003.

		11	12	13	14	15	16	17	18	19	20
Identify who the users will be	1										
Define each user identified	2										
Meet with the users	3										
Identify who the customers will be	4										
Define each customer	5										
Determine product requirements	6										
Define the market the product will be sold into	7										
Determine the feasibility of the product	8										
Consider design alternatives	9										
Determine the user interface design	10										
Determine the product design	11	1 0									
Develop the prototype	12	0.4758 0.0079	1 0								
Test the prototype	13	0.6023 0.0004	0.83623 0.0001	1 0							
Develop programs	14	0.4758 0.0079	1 0.0001	0.83623 0.0001	1 0						
Develop user documentation	15	0.52734 0.0027	0.52304 0.003	0.5682 0.0011	0.52304 0.003	1 0					
Develop user training	16	0.54464 0.0019	0.57689 0.0008	0.65922 0.0001	0.57689 0.0008	0.70214 0.0001	1 0				
Test software	17	0.70189 0.0001	0.50264 0.0046	0.48726 0.0063	0.50264 0.0046	0.34115 0.065	0.25126 0.1805	1 0			
Test user documentation	18	0.55701 0.0014	0.47923 0.0074	0.54387 0.0019	0.47923 0.0074	0.49267 0.0057	0.58868 0.0006	0.47982 0.0073	1 0		
Test user training	19	0.35008 0.0579	0.4788 0.0074	0.54505 0.0018	0.4788 0.0074	0.30543 0.1007	0.61251 0.0003	0.22239 0.2375	0.68031 0.0001	1 0	
Test product with users	20	0.53773 0.0022	0.37991 0.0384	0.38976 0.0332	0.37991 0.0384	0.44523 0.0137	0.53129 0.0025	0.28791 0.1229	0.63419 0.0002	0.55297 0.0015	1 0

Table 31. SD Correlation Matrix for Software Development Activity - User Representatives

Boxes with double-lined borders indicate p<= 0.0003.

		1	2	3	4	5	6	7	8	9	10
Identify who the users will be	1	1 0									
Define each user identified	2	0.83821 0.0001	1 0								
Meet with the users	3	0.25968 0.1658	0.32843 0.0764	1 0							
Identify who the customers will be	4	0.50498 0.0044	0.48256 0.0069	0.34139 0.0648	1 0						
Define each customer	5	0.48855 0.0062	0.53577 0.0023	0.48322 0.0068	0.89038 0.0001	1 0					
Determine product requirements	6	0.49385 0.0055	0.6272 0.0002	0.12815 0.4998	0.50978 0.004	0.33896 0.0669	1 0				
Define the market the product will be sold into	7	0.43162 0.0172	0.44031 0.0149	0.32941 0.0755	0.68205 0.0001	0.67922 0.0001	0.43258 0.017	1 0			
Determine the feasibility of the product	8	0.12584 0.5076	0.09691 0.6104	0.2161 0.2514	0.23189 0.2176	0.1285 0.4986	0.3433 0.0633	0.32894 0.0759	1 0		
Consider design alternatives	9	0.03694 0.8463	-0.05283 0.7816	0.02819 0.8824	0.07315 0.7009	-0.02515 0.8951	0.05402 0.7768	0.43855 0.0153	0.66453 0.0001	1 0	
Determine the user interface design	10	0.29808 0.1096	0.2997 0.1076	0.08594 0.6516	0.22516 0.2316	0.08472 0.6562	0.39358 0.0314	0.32983 0.0751	0.46008 0.0105	0.39561 0.0305	1 0
Determine the product design	11	-0.14636 0.4403	-0.17805 0.3465	0.11013 0.5624	0.02209 0.9077	-0.0293 0.8779	0.04253 0.8234	0.31651 0.0884	0.62825 0.0002	0.7159 0.0001	0.41082 0.0241
Develop the prototype	12	0.30895 0.0967	0.30002 0.1072	0.35563 0.0538	0.40591 0.026	0.38481 0.0358	0.41506 0.0226	0.53579 0.0023	0.34087 0.0653	0.4496 0.0127	0.27092 0.1476
Test the prototype	13	-0.15221 0.422	-0.07252 0.7033	0.07412 0.6971	0.37847 0.0392	0.27946 0.1348	0.16106 0.3952	0.21538 0.253	0.42093 0.0205	0.36119 0.0499	0.28939 0.1209
Develop programs	14	0.30449 0.1018	0.28029 0.1336	0.37114 0.0435	0.39099 0.0326	0.35603 0.0535	0.3998 0.0286	0.63657 0.0002	0.41504 0.0226	0.59931 0.0005	0.33528 0.0701
Develop user documentation	15	0.10129 0.5943	0.20186 0.2848	0.33616 0.0693	-0.04855 0.7989	0.03896 0.838	0.00914 0.9617	0.21628 0.251	0.25251 0.1782	0.34651 0.0607	0.55094 0.0016
Develop user training	16	0.13868 0.4649	0.22314 0.2359	0.25516 0.1736	-0.06866 0.7185	-0.01517 0.9366	0.05265 0.7823	0.20391 0.2798	0.17712 0.3491	0.35196 0.0565	0.55694 0.0014
Test software	17	-0.0274 0.8857	-0.00678 0.9716	-0.48393 0.0067	0.29163 0.1179	0.14388 0.4481	0.31901 0.0858	0.04028 0.8326	0.08075 0.6714	0.13274 0.4844	-0.03549 0.8523
Test user documentation	18	-0.10421 0.5837	0.05003 0.7929	-0.2448 0.1923	0.10631 0.5761	0.02488 0.8962	0.14068 0.4584	0.00619 0.9741	0.09431 0.6201	0.06411 0.7364	0.40582 0.0261
Test user training	19	0.07367 0.6988	0.19685 0.2971	0.03397 0.8586	0.06679 0.7258	0.17945 0.3427	0.12221 0.52	0.06786 0.7216	0.23856 0.2042	0.11303 0.552	0.42864 0.0181
Test product with users	20	0.03865 0.8393	0.28062 0.1331	0.11377 0.5494	0.02551 0.8935	0.12403 0.5138	0.28695 0.1242	0.15153 0.4241	0.20249 0.2832	0.11889 0.5315	0.50734 0.0042
		1	2	3	4	5	6	7	8	9	10

Table 31 (Continued). SD Correlation Matrix for Software Development Activity - User Representatives

Boxes with double-lined borders indicate p<= 0.0003.

		11	12	13	14	15	16	17	18	19	20
Identify who the users will be	1										
Define each user identified	2										
Meet with the users	3										
Identify who the customers will be	4										
Define each customer	5										
Determine product requirements	6										
Define the market the product will be sold into	7										
Determine the feasibility of the product	8										
Consider design alternatives	9										
Determine the user interface design	10										
Determine the product design	11	1									
		0									
Develop the prototype	12	0.29457	1								
		0.1141	0								
Test the prototype	13	0.3911	0.53658	1							
		0.0326	0.0022	0							
Develop programs	14	0.44017	0.86656	0.49211	1						
		0.0149	0.0001	0.0057	0						
Develop user documentation	15	0.2576	0.39298	0.18028	0.41199	1					
		0.1693	0.0317	0.3404	0.0237	0					
Develop user training	16	0.24557	0.37051	0.09367	0.41723	0.93542	1				
		0.1909	0.0438	0.6225	0.0218	0.0001	0				
Test software	17	0.04851	0.13725	0.32252	0.17584	-0.15499	-0.09611	1			
		0.799	0.4695	0.0822	0.3526	0.4135	0.6134	0			
Test user documentation	18	0.17055	-0.05906	0.22426	0.04054	0.30507	0.39387	0.35016	1		
		0.3676	0.7566	0.2335	0.8316	0.1012	0.0313	0.0578	0		
Test user training	19	0.25853	0.06402	0.03974	0.07405	0.40863	0.47739	0.11482	0.67681	1	
		0.1678	0.7368	0.8349	0.6973	0.025	0.0076	0.5457	0.0001	0	
Test product with users	20	0.1939	0.13767	0	0.12402	0.43726	0.46194	-0.04761	0.38416	0.78665	1
		0.3046	0.4682	1	0.5138	0.0157	0.0102	0.8027	0.0361	0.0001	0
		11	12	13	14	15	16	17	18	19	20

Table 32. Summary of SD Correlation Matrices for Software Development Activities

Boxes with double-lined borders indicate p <= 0.0003
for at least five of the product team members

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Identify who the users will be	1																				
Define each user identified	2	6																			
Meet with the users	3	2	1																		
Identify who the customers will be	4																				
Define each customer	5		1		4																
Determine product requirements	6																				
Define the market the product will be sold into	7				4	2	1														
Determine the feasibility of the product	8						1														
Consider design alternatives	9								2												
Determine the user interface design	10									1											
Determine the product design	11						1		1	2	2										
Develop the prototype	12						1		2	1		1									
Test the prototype	13											2	4								
Develop programs	14							1				1	5	1							
Develop user documentation	15		1							1											
Develop user training	16									1				1		4					
Test software	17										1	2		3							
Test user documentation	18	1														1					
Test user training	19	1	1	1													4		5		
Test product with users	20																1		1	3	

- Test user documentation,
  Test user training

Analyses of Variance

Table 33 contains the ANOVA summary table for the software development activities. Using $\alpha = 0.05$, all effects were statistically significant. The three-way interaction was analyzed using simple-effect F tests.

Education x product team member x activity interaction. Table 34 contains the ANOVA summary table for the simple-effect F test analysis. The analysis found the education x product team member interaction statistically significant ($\alpha = 0.05$) at the following levels of activity:

Identify who the customers will be (a_4)
Define each customer identified (a_5)
Determine product requirements (a_6)
Determine the feasibility of the product (a_8)
Consider design alternatives (a_9)
Determine the product design (a_{11})
Develop the prototype (a_{12})
Test the prototype (a_{13})
Develop programs (a_{14})
Test software (a_{17})
Test user documentation (a_{18})
Test user training (a_{19})

Table 35 contains the ANOVA summary table for the simple-simple effect F tests. Table 36 contains a summary of the effects found to be statistically significant ($\alpha = 0.05$).

Table 33. ANOVA Summary Table for the Software Development Activities

Source	*df*	*SS*	*MS*	*F*	ε[a]	*P*
<u>Between</u>						
Education(E)	1	243.44	243.44	8.74	---	0.0045
S/E	58	1615.06	27.85			
<u>Within</u>						
Product Team Member (P)	6	1395.97	232.66	76.50	0.7509	0.0000
P x E	6	123.63	20.6	6.78	0.7509	0.0000
P x S/E	348	1058.87	3.04			
Activity (A)	19	1611.14	84.80	57.69	0.4611	0.0000
A x E	19	122.96	6.47	4.40	0.4611	0.0000
A x S/E	1102	1619.76	1.47			
P x A	114	5102.76	44.76	58.80	0.2301	0.0000
P x A x E	114	286.26	2.51	3.30	0.2301	0.0000
P x A x S/E	6608[b]	5033.00	0.76			
Total	8395	18212.38				

[a] Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959)

[b] Four ratings that were omitted were replaced with the mean of the cell, therefore reducing the degrees of freedom by four.

Table 34. Simple-Effect F Tests for the Education (E) x Product Team Member (P) x Activity (a_j) Interaction

Source	*df*	*SS*	*MS*	*F*	*p*[a]
ExP @ Identify who the users will be (a_1)	6	5.28	0.88	1.16	0.3271
ExP @ Define each user identified (a_2)	6	2.69	0.45	0.59	0.6901
ExP @ Meet with the users (a_3)	6	1.74	0.29	0.38	0.8447
ExP @ Identify who the customers will be (a_4)	6	13.78	2.29	3.02	0.0131
ExP @ Define each customer (a_5)	6	15.05	2.51	3.30	0.0077
ExP @ Determine product requirements (a_6)	6	18.02	3.00	3.95	0.0022
ExP @ Define the market the product will be sold into (a_7)	6	5.56	0.93	1.22	0.2951
ExP @ Determine the feasibility of the product (a_8)	6	21.98	3.66	4.82	0.0004
ExP @ Consider design alternatives (a_9)	6	58.35	9.73	12.80	0.0000
ExP @ Determine the user interface design (a_{10})	6	2.50	0.42	0.55	0.7201
ExP @ Determine the product design (a_{11})	6	39.80	6.47	8.51	0.0000
ExP @ Develop the prototype (a_{12})	6	56.16	9.36	12.32	0.0000

[a] Probability determined using a Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959) to adjust the degrees of freedom. Epsilon for *df* for the numerator = 0.7509 and epsilon for the *df* for denominator = 0.2301.

Table 34 (Continued). Simple-Effect F Tests for the Education (E) x Product Team Member (P) x Activity (a_j) Interaction

Source	*df*	*SS*	*MS*	*F*	*P*[a]
ExP @ Test the prototype (a_{13})	6	77.77	12.96	17.05	0.0000
ExP @ Develop programs (a_{14})	6	16.16	2.69	3.54	0.0049
ExP @ Develop user documentation (a_{15})	6	6.79	1.13	1.49	0.1962
ExP @ Develop user training (a_{16})	6	6.47	1.08	1.41	0.2230
ExP @ Test software (a_{17})	6	23.38	3.90	5.13	0.0002
ExP @ Test user documentation (a_{18})	6	12.09	2.02	2.65	0.0261
ExP @ Test user training (a_{19})	6	11.33	1.89	2.48	0.0359
ExP @ Test product with users (a_{20})	6	6.45	1.08	1.41	0.2230
P x A x S/E	6608	5033.00	0.76		

[a] Probability determined using a Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959) to adjust the degrees of freedom. Epsilon for *df* for the numerator = 0.7509 and epsilon for the *df* for denominator = 0.2301.

Table 35. Simple-Simple Effect F Tests for the Education (E) x Product Team Member (p_i) x Activity (a_j) Interaction

Source	*df*	*SS*	*MS*	*F*	p^a
Identify who the customers will be (a_4)					
E @ Overall(p_1)	1	0.60	0.60	0.79	0.3742
E @ Programmer(p_2)	1	1.35	1.35	1.78	0.1826
E @ Technical Writer(p_3)	1	0.00	0.00	0.00	1.0000
E @ Training Developer(p_4)	1	2.82	2.82	3.71	0.0544
E @ Human Factors Engineer(p_5)	1	3.75	3.75	4.93	0.0265
E @ Marketing Specialist(p_6)	1	0.60	0.60	0.79	0.3742
E @ User Representatives(p_7)	1	6.67	6.67	8.77	0.0031
Define each customer identified (a_5)					
E @ Overall(p_1)	1	2.82	2.82	3.71	0.0544
E @ Programmer(p_2)	1	5.40	5.40	7.11	0.0078
E @ Technical Writer(p_3)	1	0.02	0.02	0.02	0.8823
E @ Training Developer(p_4)	1	0.82	0.82	1.07	0.3000
E @ Human Factors Engineer(p_5)	1	0.27	0.27	0.35	0.5536
E @ Marketing Specialist(p_6)	1	0.07	0.07	0.09	0.7671
E @ User Representatives(p_7)	1	6.02	6.02	7.92	0.0050

[a] Probability determined using a Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959) to adjust the *df*s for the error term ($\epsilon = 0.2301$).

Table 35 (Continued). Simple-Simple Effect F Tests for the Education (E) x Product Team Member (p_i) x Activity (a_j) Interaction

Source	*df*	*SS*	*MS*	*F*	p^a
Determine product requirements (a_6)					
E @ Overall(p_1)	1	0.27	0.27	0.35	0.5536
E @ Programmer(p_2)	1	0.02	0.02	0.02	0.8823
E @ Technical Writer(p_3)	1	0.60	0.60	0.79	0.3742
E @ Training Developer(p_4)	1	9.60	9.60	12.63	0.0004
E @ Human Factors Engineer(p_5)	1	25.35	25.35	33.36	0.0000
E @ Marketing Specialist(p_6)	1	7.35	7.35	9.67	0.0019
E @ User Representatives(p_7)	1	0.07	0.07	0.09	0.7671
Determine the feasibility of the product (a_8)					
E @ Overall(p_1)	1	0.60	0.60	0.79	0.3242
E @ Programmer(p_2)	1	0.15	0.15	0.20	0.6568
E @ Technical Writer(p_3)	1	2.02	2.02	2.65	0.1033
E @ Training Developer(p_4)	1	8.82	8.82	11.60	0.0007
E @ Human Factors Engineer(p_5)	1	26.67	26.67	35.09	0.0000
E @ Marketing Specialist(p_6)	1	10.42	10.42	13.71	0.0002
E @ User Representatives(p_7)	1	0.07	0.07	0.09	0.7671

[a] Probability determined using a Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959) to adjust the *df*s for the error term ($\epsilon = 0.2301$).

Table 35 (Continued). Simple-Simple Effect F Tests for the Education (E) x Product Team Member (p_i) x Activity (a_j) Interaction

Source	*df*	*SS*	*MS*	*F*	*P*[a]
Consider design alternatives (a_9)					
E @ Overall(p_1)	1	3.27	3.27	4.30	0.0383
E @ Programmer(p_2)	1	0.82	0.82	1.07	0.3000
E @ Technical Writer(p_3)	1	0.60	0.60	0.79	0.3742
E @ Training Developer(p_4)	1	24.07	24.07	31.67	0.0000
E @ Human Factors Engineer(p_5)	1	68.27	68.27	89.82	0.0000
E @ Marketing Specialist(p_6)	1	5.40	5.40	7.11	0.0078
E @ User Represen-tatives(p_7)	1	28.02	28.02	36.86	0.0000
Determine the product design (a_{11})					
E @ Overall(p_1)	1	0.07	0.07	0.09	0.7671
E @ Programmer(p_2)	1	0.02	0.02	0.02	0.8823
E @ Technical Writer(p_3)	1	4.82	4.82	6.34	0.0119
E @ Training Developer(p_4)	1	1.67	1.67	2.19	0.1386
E @ Human Factors Engineer(p_5)	1	54.15	54.15	71.25	0.0000
E @ Marketing Specialist(p_6)	1	1.35	1.35	1.78	0.1826
E @ User Represen-tatives(p_7)	1	6.02	6.02	7.92	0.0050

[a] Probability determined using a Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959) to adjust the *df*s for the error term (ϵ = 0.2301).

Table 35 (Continued). Simple-Simple Effect F Tests for the Education (E) x Product Team Member (p_i) x Activity (a_j) Interaction

Source	*df*	*SS*	*MS*	*F*	p^a
Develop the prototype (a_{12})					
E @ Overall(p_1)	1	2.02	2.02	2.65	0.1033
E @ Programmer(p_2)	1	0.02	0.02	0.02	0.8823
E @ Technical Writer(p_3)	1	14.02	14.02	18.44	0.0000
E @ Training Developer(p_4)	1	11.27	11.27	14.82	0.0001
E @ Human Factors Engineer(p_5)	1	91.27	91.27	120.09	0.0000
E @ Marketing Specialist(p_6)	1	3.75	3.75	4.93	0.0265
E @ User Representatives(p_7)	1	4.27	4.27	5.61	0.0179
Test the prototype (a_{13})					
E @ Overall(p_1)	1	1.67	1.67	2.19	0.1386
E @ Programmer(p_2)	1	9.60	9.60	12.63	0.0004
E @ Technical Writer(p_3)	1	13.07	13.07	17.19	0.0000
E @ Training Developer(p_4)	1	8.07	8.07	10.61	0.0011
E @ Human Factors Engineer(p_5)	1	70.42	70.42	92.65	0.0000
E @ Marketing Specialist(p_6)	1	2.02	2.02	2.65	0.1033
E @ User Representatives(p_7)	1	29.40	29.40	38.68	0.0000

[a] Probability determined using a Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959) to adjust the *df*s for the error term ($\epsilon = 0.2301$).

Table 35 (Continued). Simple-Simple Effect F Tests for the Education (E) x Product Team Member (p_i) x Activity (a_j) Interaction

Source	*df*	*SS*	*MS*	*F*	P^a
Develop programs (a_{14})					
E @ Overall(p_1)	1	2.82	2.82	3.71	0.0544
E @ Programmer(p_2)	1	0.07	0.07	0.09	0.7671
E @ Technical Writer(p_3)	1	2.02	2.02	2.65	0.1033
E @ Training Developer(p_4)	1	2.82	2.82	3.71	0.0544
E @ Human Factors Engineer(p_5)	1	29.40	29.40	38.68	0.0000
E @ Marketing Specialist(p_6)	1	1.67	1.67	2.19	0.1386
E @ User Representatives(p_7)	1	1.67	1.67	2.19	0.1386
Test software (a_{17})					
E @ Overall(p_1)	1	0.27	0.27	0.35	0.5536
E @ Programmer(p_2)	1	0.02	0.02	0.02	0.8823
E @ Technical Writer(p_3)	1	1.07	1.07	1.40	0.2361
E @ Training Developer(p_4)	1	0.00	0.00	0.00	1.0000
E @ Human Factors Engineer(p_5)	1	25.35	25.35	33.36	0.0000
E @ Marketing Specialist(p_6)	1	0.27	0.27	0.35	0.5536
E @ User Representatives(p_7)	1	0.42	0.42	0.55	0.4590

[a] Probability determined using a Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959) to adjust the *df*s for the error term (ϵ = 0.2301).

Table 35 (Continued). Simple-Simple Effect F Tests for the Education (E) x Product Team Member (p_i) x Activity (a_j) Interaction

Source	*df*	*SS*	*MS*	*F*	*p*[a]
Test user documentation (a_{18})					
E @ Overall(p_1)	1	0.42	0.42	0.55	0.4590
E @ Programmer(p_2)	1	1.35	1.35	1.78	0.1826
E @ Technical Writer(p_3)	1	0.82	0.82	1.07	0.3000
E @ Training Developer(p_4)	1	0.02	0.02	0.02	0.8823
E @ Human Factors Engineer(p_5)	1	14.02	14.02	18.44	0.0000
E @ Marketing Specialist(p_6)	1	1.07	1.07	1.40	0.2361
E @ User Represen-tatives(p_7)	1	1.35	1.35	1.78	0.1826
Test user training (a_{19})					
E @ Overall(p_1)	1	0.82	0.82	1.07	0.3000
E @ Programmer(p_2)	1	0.82	0.82	1.07	0.3000
E @ Technical Writer(p_3)	1	12.15	12.15	15.99	0.0001
E @ Training Developer(p_4)	1	0.60	0.60	0.79	0.3742
E @ Human Factors Engineer(p_5)	1	7.35	7.35	9.67	0.0019
E @ Marketing Specialist(p_6)	1	2.82	2.82	3.71	0.0544
E @ User Represen-tatives(p_7)	1	2.02	2.02	2.65	0.1033
PxAxS/E	6608	5033.00	0.76		

[a] Probability determined using a Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959) to adjust the *df*s for the error term (ϵ = 0.2301).

Table 36. Summary for the Education x Product Team Member x Activity Interaction

Activity	*Product Team Member*	*Education*	*Statistics* Mean	*Statistics* Standard Error
Identify who the customers will be(a_4)	Human Factors Engineer(p_5)	HFE	3.83	0.19
		SD	3.33	0.24
	User Representatives(p_7)	HFE	2.40	0.22
		SD	3.07	0.23
Define each customer(a_5)	Programmer(p_2)	HFE	2.17	0.18
		SD	1.57	0.13
	User Representatives(p_7)	HFE	2.27	0.21
		SD	2.90	0.26
Define product requirements(a_6)	Training Developer(p_4)	HFE	3.10	0.24
		SD	2.30	0.24
	Human Factors Engineer(p_5)	HFE	4.57	0.12
		SD	3.27	0.24
	Marketing Specialist(p_6)	HFE	4.33	0.14
		SD	3.63	0.26
Determine the feasibility of the product(a_8)	Training Developer(p_4)	HFE	2.43	0.21
		SD	1.67	0.16
	Human Factors Engineer(p_5)	HFE	3.83	0.21
		SD	2.50	0.23
	Marketing Specialist(p_6)	HFE	3.83	0.22
		SD	3.00	0.31

Table 36 (Continued). Summary for the Education x Product Team Member x Activity Interaction

Activity	Product Team Member	Education	Statistics: Mean	Statistics: Standard Error
Consider design alternatives(a_9)	Overall(p_1)	HFE	4.47	0.13
		SD	4.00	0.13
	Training Developer(p_4)	HFE	2.73	0.22
		SD	1.47	0.13
	Human Factors Engineer(p_5)	HFE	4.77	0.10
		SD	2.63	0.24
	Marketing Specialist(p_6)	HFE	2.67	0.18
		SD	2.07	0.2
	User Representatives(p_7)	HFE	3.57	0.21
		SD	2.20	0.25
Determine the product design(a_{11})	Technical Writer(p_3)	HFE	2.37	0.18
		SD	1.80	0.19
	Human Factors Engineer(p_5)	HFE	4.40	0.15
		SD	2.50	0.23
	User Representatives(p_7)	HFE	3.07	0.21
		SD	2.43	0.26
Develop the prototype(a_{12})	Technical Writer(p_3)	HFE	2.43	0.22
		SD	1.47	0.16
	Training Developer(p_4)	HFE	2.43	0.25
		SD	1.57	0.15
	Human Factors Engineer(p_5)	HFE	4.50	0.14
		SD	2.03	0.24
	Marketing Specialist(p_6)	HFE	1.83	0.16
		SD	1.33	0.12
	User Representatives(p_7)	HFE	2.13	0.23
		SD	1.60	0.17

Table 36 (Continued). Summary for the Education x Product Team Member x Activity Interaction

Activity	Product Team Member	Education	Statistics: Mean	Statistics: Standard Error
Test the prototype(a_{13})	Programmer(p_2)	HFE	3.47	0.24
		SD	4.27	0.17
	Technical Writer(p_3)	HFE	2.67	0.25
		SD	1.73	0.19
	Training Developer(p_4)	HFE	2.70	0.28
		SD	1.97	0.18
	Human Factors Engineer(p_5)	HFE	4.50	0.15
		SD	2.33	0.25
	User Representatives(p_7)	HFE	4.27	0.24
		SD	2.87	0.29
Develop Programs(a_{14})	Human Factors Engineer(p_5)	HFE	3.03	0.19
		SD	1.63	0.16
Test software(a_{17})	Human Factors Engineer(p_5)	HFE	3.77	0.24
		SD	2.47	0.21
Test user documentation(a_{18})	Human Factors Engineer(p_5)	HFE	4.43	0.18
		SD	4.20	0.17
Test user training(a_{19})	Technical Writer(p_3)	HFE	3.90	0.19
		SD	3.00	0.26
	Human Factors Engineer(p_5)	HFE	4.40	0.17
		SD	3.70	0.22

Education x product team member interaction. Table 37 has the ANOVA summary table for the simple-effect analysis for the education x product team member interaction. The analysis found education statistically significant (α = 0.05) for five of the seven product team members: overall, technical writer, training developer, human factors engineer, marketing specialist. For each of these product team members, HFEs rated the participation in all activities higher than the SDs (Table 38).

Education x activity interaction. Table 39 has the ANOVA summary table for the simple-effect analysis for the education x activity interaction. The analysis resulted in education being significant for 12 of the 20 activities:

Define each user identified (a_2)
Determine product requirements (a_6)
Determine the feasibility of the product (a_8)
Consider design alternatives (a_9)
Determine the product design (a_{11})
Develop the prototype (a_{12})
Test the prototype (a_{13})
Develop programs (a_{14})
Develop user training (a_{16})
Test user documentation (a_{18})
Test user training (a_{19})
Test product with users (a_{20})

For each of these activities HFEs rated the participation of all product team members higher than the SDs (Table 40).

Product team member x activity interaction. Table 41 contains the ANOVA summary table for the simple-effect analysis for the product team member x activity interaction. All interactions were statistically significant (α = 0.05).

Table 37. Simple-Effect F Tests for the Education (E) x Product Team Member (p_i) Interaction

Source	*df*	*SS*	*MS*	*F*	*P*[a]
E @ Overall(p_1)	1	13.87	13.87	4.56	0.0337
E @ Programmer(p_2)	1	4.44	4.44	1.46	0.2280
E @ Technical Writer(p_3)	1	36.40	36.40	11.97	0.0006
E @ Training Developer(p_4)	1	29.45	29.45	9.68	0.0021
E @ Human Factors Engineer(p_5)	1	247.52	247.52	81.39	0.0000
E @ Marketing Specialist(p_6)	1	24.37	24.37	8.01	0.0050
E @ User Representatives(p_7)	1	11.02	11.02	3.62	0.0582
P x S/E	348	1058.37	3.04		

[a] Probability determined using a Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959) to adjust the degrees of freedom for the error term (ϵ = 0.7509).

Table 38. Summary for the Education x Product Team Member Interaction

		Statistics	
Product Team Member	*Education*	*Mean*	*Standard Error*
Overall(p_1)	HFE	4.33	0.03
	SD	4.12	0.04
Technical Writer(p_3)	HFE	3.19	0.06
	SD	2.84	0.06
Training Developer(p_4)	HFE	3.38	0.06
	SD	3.07	0.06
Human Factors Engineer(p_5)	HFE	4.14	0.05
	SD	3.24	0.06
Marketing Specialist(p_6)	HFE	3.10	0.06
	SD	2.82	0.70

Table 39. Simple-Effect F Tests for the Education (E) x Activity (a_i) Interaction

Source	*df*	*SS*	*MS*	*F*	*P*[a]
E @ Identify who the users will be (a_1)	1	4.40	4.40	3.00	0.839
E @ Define each user identified (a_2)	1	6.94	6.94	4.72	0.0303
E @ Meet with the users (a_3)	1	1.74	1.74	1.18	0.2779
E @ Identify who the customers will be (a_4)	1	2.00	2.00	1.36	0.2441
E @ Define each customer (a_5)	1	0.34	0.34	0.23	0.6317
E @ Determine product requirements (a_6)	1	18.02	18.02	12.26	0.0005
E @ Define the market the product will be sold into (a_7)	1	0.29	0.29	0.20	0.6549
E @ Determine the feasibility of the product (a_8)	1	26.75	26.75	18.20	0.0000
E @ Consider design alternatives (a_9)	1	72.09	72.09	49.04	0.0000
E @ Determine the user interface design (a_{10})	1	0.69	0.69	0.47	0.4933
E @ Determine the product design (a_{11})	1	28.29	28.29	19.15	0.0000
E @ Develop the prototype (a_{12})	1	70.44	70.44	47.92	0.0000

[a] Probability determined using a Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959) to adjust the *df*s for the error term (ϵ = 0.4611).

Table 39 (Continued). Simple-Effect F Tests for the Education (E) x Activity (a_i) Interaction

Source	*df*	*SS*	*MS*	*F*	*p*[a]
E @ Test the prototype (a_{13})	1	56.47	56.47	38.42	0.000
E @ Develop programs (a_{14})	1	24.29	24.29	16.52	0.0001
E @ Develop user documentation (a_{15})	1	3.81	3.81	2.59	0.1082
E @ Develop user training (a_{16})	1	11.67	11.67	7.94	0.0050
E @ Test software (a_{17})	1	4.00	4.00	2.72	0.0997
E @ Test user documentation (a_{18})	1	6.94	6.94	4.72	0.0303
E @ Test user training (a_{19})	1	15.24	15.24	10.37	0.0014
E @ Test product with users (a_{20})	1	12.00	12.00	8.17	0.0044
A x S/E	1102	1619.76	1.47		

[a] Probability determined using a Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959) to adjust the *df*s for the error term (ϵ = 0.4611).

Table 40. Statistics for the Effects for the Education x Activity Interaction

Activity	*Education*	*Statistics*	
		Mean	*Standard Error*
Define each user identified(a_2)	HFE	4.24	0.08
	SD	3.98	0.08
Determine product requirements(a_6)	HFE	3.96	0.08
	SD	3.54	0.10
Determine the feasibility of the product(a_8)	HFE	3.30	0.10
	SD	2.79	0.10
Consider design alternatives(a_9)	HFE	3.49	0.09
	SD	2.66	0.10
Determine the product design(a_{11})	HFE	3.27	0.09
	SD	2.75	0.10
Develop the prototype(a_{12})	HFE	3.18	0.11
	SD	2.36	0.11
Test the prototype(a_{13})	HFE	3.43	0.11
	SD	2.70	0.11
Develop programs(a_{14})	HFE	2.82	0.10
	SD	2.34	0.11
Develop user training(a_{16})	HFE	3.54	0.09
	SD	3.21	0.10
Test user documentation(a_{18})	HFE	3.79	0.10
	SD	3.53	0.10
Test user training(a_{19})	HFE	3.77	0.10
	SD	3.39	0.10
Test product with users(a_{20})	HFE	4.01	0.09
	SD	3.68	0.10

Table 41. Simple-Effect F Tests for the Product Team Member (P) x Activity (a_i) Interaction

Source	*df*	*SS*	*MS*	*F*	*P*[a]
P @ Identify who the users will be (a_1)	6	94.36	15.73	20.66	0.0000
P @ Define each user identified (a_2)	6	95.13	15.86	20.83	0.0000
P @ Meet with the users (a_3)	6	143.76	23.96	31.48	0.0000
P @ Identify who the customers will be (a_4)	6	218.87	36.48	47.92	0.0000
P @ Define each customer (a_5)	6	284.32	47.39	62.25	0.0000
P @ Determine product requirements (a_6)	6	178.33	29.72	39.05	0.0000
P @ Define the market the product will be sold into (a_7)	6	416.79	69.47	91.26	0.0000
P @ Determine the feasibility of the product (a_8)	6	271.16	45.19	59.37	0.0000
P @ Consider design alternatives (a_9)	6	364.00	60.67	79.70	0.0000
P @ Determine the user interface design (a_{10})	6	367.99	91.33	80.57	0.0000
P @ Determine the product design (a_{11})	6	270.93	45.15	59.32	0.0000
P @ Develop the prototype (a_{12})	6	534.12	89.02	116.95	0.0000

[a] Probability determined using a Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959) to adjust the degrees of freedom. Epsilon for *df* for the numerator = 0.7509 and epsilon for the *df* for denominator = 0.2301

Table 41 (Continued). Simple-Effect F Tests for the Product Team Member (P) x Activity (a_i) Interaction

Source	*df*	*SS*	*MS*	*F*	*P*[a]
P @ Test the prototype (a_{13})	6	376.29	62.72	82.39	0.0000
P @ Develop programs (a_{14})	6	693.73	115.62	151.89	0.0000
P @ Develop user documentation (a_{15})	6	361.83	60.30	79.22	0.0000
P @ Develop user training (a_{16})	6	372.36	32.06	81.53	0.0000
P @ Test software (a_{17})	6	432.58	72.10	94.71	0.0000
P @ Test user documentation (a_{18})	6	391.13	65.19	85.64	0.0000
P @ Test user training (a_{19})	6	413.13	68.85	90.46	0.0000
P @ Test product with users (a_{20})	6	217.92	36.32	47.71	0.0000
P x A x S/E	6608	5033.00	0.76		

[a] Probability determined using a Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959) to adjust the degrees of freedom. Epsilon for *df* for the numerator = 0.7509 and epsilon for the *df* for denominator = 0.2301

The Newman-Keuls post-hoc test was conducted to probe for significance. Table 42 contains a summary of this analysis.

Education. The analysis of the main effect of education showed that HFEs (mean = 3.55, standard error = 0.02) rated items higher than SDs (mean = 3.21, standard error = 0.02).

Product team member. The main effect of product team member was analyzed using the Newman-Keuls post-hoc test. This analysis indicated that there was no statistical significant difference (α = 0.05) between any of the ratings for product team member (Table 43).

Activity. The main effect of activity was analyzed using the Newman-Keuls post-hoc test. Table 44 contains a summary of this analysis.

Table 42. Summary of Product Team Member x Activity Interaction

Activity	*Product Team Member*[a]	*Mean*	*Standard Error*	*Grouping*[b]
Identify who the customers will be(a_1)	Programmer(p_2)	3.23	0.17	A
	User Representatives(p_7)	3.93	0.17	AB
	Technical Writer(p_3)	4.32	0.14	B
	Marketing Specialist(p_6)	4.45	0.12	B
	Training Developer(p_4)	4.48	0.13	B
	Human Factors Engineer(p_5)	4.55	0.12	B
	Overall(p_1)	4.75	0.06	B
Define each user identified(a_2)	Programmer(p_2)	3.05	0.17	A
	User Representatives(p_7)	3.92	0.18	B
	Overall(p_1)	4.15	0.09	B
	Marketing Specialist(p_6)	4.25	0.13	B
	Technical Writer(p_3)	4.35	0.15	B
	Human Factors Engineer(p_5)	4.50	0.13	B
	Training Developer(p_4)	4.55	0.11	B
Meet with the users(a_3)	Programmer(p_2)	2.67	0.18	A
	Overall(p_1)	3.57	0.16	B
	Technical Writer(p_3)	3.63	0.16	B
	Marketing Specialist(p_6)	4.03	0.15	BC
	User Representatives(p_7)	4.08	0.18	BC
	Human Factors Engineer(p_5)	4.37	0.11	BC
	Training Developer(p_4)	4.57	0.10	C

[a] Ascending order by value of the means.

[b] Means with the same letter are not significantly different.

Table 42 (Continued). Summary of Product Team Member x Activity Interaction

Activity	*Product Team Member*[a]	*Mean*	*Standard Error*	*Grouping*[b]
Develop user documentation(a_4)	Programmer(p_2)	2.52	0.16	A
	User Representatives(p_7)	2.73	0.16	AB
	Technical Writer(p_3)	3.27	0.15	BC
	Training Developer(p_4)	3.35	0.17	BC
	Human Factors Engineer(p_5)	3.58	0.15	C
	Overall(p_1)	4.20	0.09	D
	Marketing Specialist(p_6)	4.73	0.09	E
Define each customer(a_5)	Programmer(p_2)	1.87	0.12	A
	Technical Writer(p_3)	2.52	0.16	AB
	User Representatives(p_7)	2.58	0.17	B
	Training Developer(p_4)	3.02	0.18	B
	Overall(p_1)	3.05	0.12	B
	Human Factors Engineer(p_5)	3.20	0.16	C
	Marketing Specialist(p_6)	4.73	0.07	C
Determine product requirements(a_6)	Training Developer(p_4)	2.70	0.17	A
	Technical Writer(p_3)	2.90	0.18	A
	Human Factors Engineer(p_5)	3.92	0.16	B
	Programmer(p_2)	3.95	0.15	B
	Marketing Specialist(p_6)	3.98	0.15	B
	User Representatives(p_7)	4.10	0.15	B
	Overall(p_1)	4.70	0.07	B

[a] Ascending order by value of the means.

[b] Means with the same letter are not significantly different.

Table 42 (Continued). Summary of Product Team Member x Activity Interaction

Activity	*Product Team Member*[a]	*Mean*	*Standard Error*	*Grouping*[b]
Define the market the product will be sold into(a_7)	Programmer(p_2)	1.85	0.12	A
	User Representatives(p_7)	2.20	0.16	AB
	Training Developer(p_4)	2.38	0.17	AB
	Technical Writer(p_3)	2.77	0.17	B
	Human Factors Engineer(p_5)	2.87	0.15	B
	Overall(p_1)	3.82	0.11	C
	Marketing Specialist(p_6)	4.97	0.02	D
Determine the feasibility of the product(a_8)	Technical Writer(p_3)	1.92	0.13	A
	Training Developer(p_4)	2.05	0.14	A
	User Representatives(p_7)	2.77	0.19	B
	Human Factors Engineer(p_5)	3.17	0.18	BC
	Marketing Specialist(p_6)	3.42	0.20	C
	Programmer(p_2)	3.65	0.17	C
	Overall(p_1)	4.33	0.09	D
Consider design alternatives(a_9)	Technical Writer(p_3)	1.93	0.12	A
	Training Developer(p_4)	2.10	0.15	A
	Marketing Specialist(p_6)	2.37	0.14	AB
	User Representatives(p_7)	2.88	0.18	B
	Human Factors Engineer(p_5)	3.70	0.19	C
	Overall(p_1)	4.23	0.10	CD
	Programmer(p_2)	4.32	0.11	D

[a] Ascending order by value of the means.

[b] Means with the same letter are not significantly different.

Table 42 (Continued). Summary of Product Team Member x Activity Interaction

Activity	*Product Team Member*[a]	*Mean*	*Standard Error*	*Grouping*[b]
Determine the user interface design(a_{10})	Marketing Specialist(p_6)	2.35	0.15	A
	Technical Writer(p_3)	2.43	0.16	A
	Training Developer(p_4)	2.98	0.16	A
	Programmer(p_2)	3.87	0.14	B
	User Representatives(p_7)	4.03	0.14	B
	Overall(p_1)	4.58	0.08	C
	Human Factors Engineer(p_5)	4.87	0.06	C
Determine the product design(a_{11})	Technical Writer(p_3)	2.08	0.14	A
	Marketing Specialist(p_6)	2.28	0.15	A
	Training Developer(p_4)	2.30	0.15	A
	User Representatives(p_7)	2.75	0.17	A
	Human Factors Engineer(p_5)	3.45	0.18	B
	Programmer(p_2)	3.98	0.14	BC
	Overall(p_1)	4.20	0.10	C
Develop the prototype(a_{12})	Marketing Specialist(p_6)	1.58	0.10	A
	User Representatives(p_7)	1.87	0.15	A
	Technical Writer(p_3)	1.95	0.15	A
	Training Developer(p_4)	2.00	0.16	A
	Human Factors Engineer(p_5)	3.27	0.21	B
	Overall(p_1)	4.18	0.11	C
	Programmer(p_2)	4.55	0.08	C

[a] Ascending order by value of the means.

[b] Means with the same letter are not significantly different.

Table 42 (Continued). Summary of Product Team Member x Activity Interaction

Activity	*Product Team Member*[a]	*Mean*	*Standard Error*	*Grouping*[b]
Test the prototype(a_{13})	Marketing Specialist(p_6)	1.62	0.10	A
	Technical Writer(p_3)	2.20	0.17	AB
	Training Developer(p_4)	2.33	0.17	B
	Human Factors Engineer(p_5)	3.42	0.20	C
	User Representatives(p_7)	3.57	0.21	C
	Programmer(p_2)	3.87	0.16	C
	Overall(p_1)	4.43	0.12	D
Develop programs(a_{14})	Marketing Specialist(p_6)	1.50	0.09	A
	User Representatives(p_7)	1.63	0.12	A
	Technical Writer(p_3)	1.75	0.12	AB
	Training Developer(p_4)	1.75	0.12	AB
	Human Factors Engineer(p_5)	2.33	0.15	B
	Overall(p_1)	4.22	0.10	C
	Programmer(p_2)	4.90	0.04	D
Develop user documentation(a_{15})	Marketing Specialist(p_6)	1.97	0.13	A
	User Representatives(p_7)	2.92	0.18	B
	Programmer(p_2)	3.02	0.14	B
	Training Developer(p_4)	3.43	0.14	B
	Human Factors Engineer(p_5)	3.55	0.16	B
	Overall(p_1)	4.50	0.08	C
	Technical Writer(p_3)	4.95	0.03	D

[a] Ascending order by value of the means.

[b] Means with the same letter are not significantly different.

Table 42 (Continued). Summary of Product Team Member x Activity Interaction

Activity	*Product Team Member*[a]	*Mean*	*Standard Error*	*Grouping*[b]
Develop user training(a_{16})	Marketing Specialist(p_6)	1.88	0.13	A
	Programmer(p_2)	2.45	0.15	AB
	User Representatives(p_7)	3.07	0.19	BC
	Human Factors Engineer(p_5)	3.57	0.15	CD
	Technical Writer(p_3)	3.63	0.14	CD
	Overall(p_1)	4.12	0.12	D
	Training Developer(p_4)	4.92	0.07	E
Test software(a_{17})	Marketing Specialist(p_6)	1.83	0.13	A
	Technical Writer(p_3)	2.17	0.17	AB
	Training Developer(p_4)	2.60	0.16	BC
	Human Factors Engineer(p_5)	3.12	0.18	CD
	User Representatives(p_7)	3.25	0.19	D
	Programmer(p_2)	4.45	0.12	E
	Overall(p_1)	4.73	0.07	E
Test user documentation(a_{18})	Marketing Specialist(p_6)	2.13	0.13	A
	Programmer(p_2)	2.28	0.13	A
	Training Developer(p_4)	3.75	0.15	B
	Human Factors Engineer(p_5)	3.95	0.16	BC
	Overall(p_1)	4.28	0.11	BCD
	User Representatives(p_7)	4.45	0.12	CDE
	Technical Writer(p_3)	4.75	0.09	DE

[a] Ascending order by value of the means.

[b] Means with the same letter are not significantly different.

Table 42 (Continued). Summary of Product Team Member x Activity Interaction

Activity	*Product Team Member*[a]	*Mean*	*Standard Error*	*Grouping*[b]
Test user training(a_{19})	Programmer(p_2)	2.12	0.13	A
	Marketing Specialist(p_6)	2.15	0.14	A
	Technical Writer(p_3)	3.45	0.17	B
	Overall(p_1)	4.02	0.13	BC
	Human Factors Engineer(p_5)	4.05	0.15	BC
	User Representatives(p_7)	4.42	0.13	CD
	Training Developer(p_4)	4.83	0.09	D
Test product with users(a_{20})	Programmer(p_2)	2.83	0.16	A
	Marketing Specialist(p_6)	2.95	0.17	A
	Technical Writer(p_3)	3.32	0.19	A
	Human Factors Engineer(p_5)	4.37	0.13	B
	Training Developer(p_4)	4.40	0.14	B
	Overall(p_1)	4.42	0.10	B
	User Representatives(p_7)	4.63	0.12	B

[a] Ascending order by value of the means.

[b] Means with the same letter are not significantly different.

Table 43. Summary of the Main Effect of Product Team Member (p_i)

Product Team Member[a]	*Mean*	*Standard Error*	*Grouping*[b]
Marketing Specialist(p_6)	2.96	0.04	A
Technical Writer(p_3)	3.01	0.04	A
Training Developer(p_4)	3.23	0.04	A
Programmer(p_2)	3.27	0.04	A
User Representatives(p_7)	3.29	0.04	A
Human Factors Engineer(p_5)	3.69	0.04	A
Overall(p_1)	4.22	0.03	A

[a] Ascending order by value of the means.

[b] Means with the same letter are not significantly different.

Table 44. Summary of the Main Effect of Activity (p_i)

Activity[a]	*Mean*	*Standard Error*	*Grouping*[b]
Develop programs(a_{14})	2.58	0.08	A
Develop the prototype(a_{12})	2.77	0.08	AB
Define the market the product will be sold into(a_7)	2.98	0.07	ABC
Define each customer(a_5)	3.00	0.07	ABC
Determine the product design(a_{11})	3.01	0.07	ABC
Determine the feasibility of the product(a_8)	3.04	0.07	ABC
Test the prototype(a_{13})	3.06	0.08	ABCD
Consider design alternatives(a_9)	3.08	0.07	ABCD
Test software(a_{17})	3.16	0.08	ABCD
Develop user training(a_{16})	3.38	0.07	ABCDE
Identify who the customers will be(a_{15})	3.48	0.06	ABCDE
Develop user documentation(a_4)	3.48	0.07	ABCDE
Test user training(a_{19})	3.58	0.07	ABCDE
Determine the user interface design(a_{10})	3.59	0.07	ABCDE
Test user documentation(a_{18})	3.66	0.07	ABCDE
Determine product requirements(a_6)	3.75	0.07	BCDE
Meet with the users(a_3)	3.85	0.06	CDE
Test product with users(a_{20})	3.85	0.07	CDE
Define each user identified(a_2)	4.11	0.06	DE
Identify who the users will be(a_1)	4.25	0.06	DE

[a] Ascending order by value of the means.

[b] Means with the same letter are not significantly different.

RESULTS - USABILITY INFORMATION QUESTIONNAIRE

Interitem correlation

HFE results. The correlation tables (Tables 45 - 48) indicate which activities were correlated highly ($p \leq 0.0006$). Table 49 contains the total number of interitem correlations that were correlated highly ($p \leq 0.0006$) summed across all of the points in development for SDs. For instance "type of user errors" (Type 1) and "frequency of user errors" (Type 2) were correlated highly ($p \leq 0.0006$) for four out of four points in development. As Table 49 indicates, the following types of usability information were correlated highly for four out of four points in development:

- Type of user errors,
  Frequency of user errors
- Frequency of user errors,
  Number of user errors
- Motivation to use the software,
  User productivity

SD results. The correlation tables (Tables 50 - 53) indicate which types of usability information were correlated highly ($p \leq 0.0006$). Table 54 contains the total number of interitem correlations that were correlated highly ($p \leq 0.0006$) summed across all of the points in development for SDs. As Table 54 indicates, the following types of usability information were correlated highly for four out of four points in development:

- Data from studies conducted on similar products or product features,
  Data from a market research project

Table 45. HFE Correlation Matrix for Type of Usability Information - No Code Has Been Written

Boxes with double-lined borders indicate p <= 0.0006.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Type of user errors	1	1													
		0													
Frequency of user errors	2	0.69595	1												
		0.0001	0												
Number of user errors	3	0.7711	0.7711	1											
		0.0001	0.0001	0											
Time for user to recover	4	0.80578	0.61693	0.63678	1										
from an error		0.0001	0.0003	0.0002	0										
Reacquisition of skills after	5	0.67173	0.49018	0.59645	0.58355	1									
time away from the software		0.0001	0.006	0.0005	0.0007	0									
Motivation to use the	6	0.30441	0.20928	0.23028	0.28361	0.46008	1								
software		0.1019	0.267	0.2209	0.1288	0.0105	0								
User productivity	7	0.55174	0.36148	0.34542	0.51405	0.64752	0.60714	1							
		0.0016	0.0497	0.0615	0.0037	0.0001	0.0004	0							
Team member's opinion	8	0.2325	-0.0581	0.05025	0.35199	0.15617	-0.0546	0.05455	1						
		0.2163	0.7603	0.792	0.0564	0.4099	0.7746	0.7746	0						
User representative's opinion	9	0.2804	0.01752	0.13636	0.42452	0.07063	-0.148	0.02467	0.64071	1					
		0.1334	0.9268	0.4724	0.0194	0.7107	0.435	0.897	0.0001	0					
Designs of competitors	10	0.14524	0.00908	0.18835	0.09303	0.21951	0.05112	0.07668	0.6247	0.34139	1				
		0.4438	0.962	0.3189	0.6249	0.2438	0.7885	0.6871	0.0002	0.0648	0				
Guidelines developed by	11	0.57558	0.47156	0.43168	0.61703	0.36335	0.41006	0.46864	0.38776	0.46765	0.24223	1			
human factors experts		0.0009	0.0085	0.0172	0.0003	0.0484	0.0244	0.009	0.0342	0.0092	0.1972	0			
Data from studies conducted	12	0.38629	0.48976	0.4115	0.29563	0.44483	0.3302	0.2525	0.02967	-0.0984	0.01853	0.43186	1		
on similar prod. or features		0.035	0.006	0.0239	0.1127	0.0138	0.0747	0.1782	0.8763	0.6049	0.9226	0.0172	0		
Data from a market research	13	0.38629	0.48976	0.4115	0.39203	0.5375	0.3302	0.54385	-0.1187	0.03578	0.01853	0.43186	0.57746	1	
project		0.035	0.006	0.0239	0.0321	0.0022	0.0747	0.0019	0.5322	0.8511	0.9226	0.0172	0.0008	0	
Data from a study conducted	14	0.50832	0.50832	0.32483	0.42211	0.46516	0.16595	0.45636	-0.0317	0.05732	-0.1188	0.465	0.69945	0.69945	1
with representative users		0.0041	0.0041	0.0799	0.0201	0.0096	0.3808	0.0113	0.868	0.7635	0.5319	0.0096	0.0001	0.0001	0

Table 46. HFE Correlation Matrix for Type of Usability Information - The Code Is Being Written

Boxes with double-lined borders indicate p <= 0.0006.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Type of user errors	1	1													
		0													
Frequency of user errors	2	0.76923	1												
		0.0001	0												
Number of user errors	3	0.57093	0.77244	1											
		0.001	0.0001	0											
Time for user to recover from an error	4	0.62879	0.62879	0.61964	1										
		0.0002	0.0002	0.0003	0										
Reacquisition of skills after time away from the software	5	0.27735	0.41603	0.24218	0.21592	1									
		0.1378	0.0222	0.1973	0.2518	0									
Motivation to use the software	6	-0.0329	-0.0329	-0.1837	-0.1228	0.47405	1								
		0.8631	0.8631	0.3312	0.5179	0.0081	0								
User productivity	7	0.07563	0.07563	-0.1222	-0.0265	0.40901	0.60751	1							
		0.6912	0.6912	0.5202	0.8895	0.0248	0.0004	0							
Team member's opinion	8	-0.187	-0.187	-0.2612	-0.1747	0	-0.016	-0.239	1						
		0.3225	0.3225	0.1632	0.3559	1	0.9332	0.2034	0						
User representative's opinion	9	0	0	-0.0704	0.00897	0.13841	0.07873	0.1019	0.25195	1					
		1	1	0.7117	0.9625	0.4658	0.6792	0.5921	0.1792	0					
Designs of competitors	10	0.04675	0.04675	0.01633	-0.1529	0.16855	0.01598	0.23899	0.19318	0.44791	1				
		0.8062	0.8062	0.9318	0.42	0.3733	0.9332	0.2034	0.3064	0.0131	0				
Guidelines developed by human factors experts	11	-0.0414	-0.0414	0.00724	-0.1161	0.1494	0.32579	-0.0163	0.01007	0.07444	-0.3123	1			
		0.8279	0.8279	0.9697	0.5411	0.4307	0.0789	0.9319	0.9579	0.6958	0.093	0			
Data from studies conducted on similar prod. or features	12	0.29056	0.29056	0.07612	0.02262	0.34922	0.52974	0.35232	-0.1884	0.10634	0.07063	0.18783	1		
		0.1193	0.1193	0.6893	0.9056	0.0586	0.0026	0.0562	0.3189	0.576	0.7107	0.3203	0		
Data from a market research project	13	0.20769	0.20769	-0.0635	0.00808	0.37442	0.51472	0.50025	-0.0252	0.27984	0.27767	0.06713	0.61889	1	
		0.2708	0.2708	0.739	0.9662	0.0415	0.0036	0.0049	0.8947	0.1342	0.1374	0.7245	0.0003	0	
Data from a study conducted with representative users	14	0.44449	0.44449	0.20003	0.26352	0.24656	0.41492	0.40673	-0.4073	0.11261	-0.0914	0.23575	0.71464	0.4708	1
		0.0139	0.0139	0.2892	0.1594	0.189	0.0226	0.0257	0.0255	0.5535	0.6309	0.2098	0.0001	0.0086	0
		1	2	3	4	5	6	7	8	9	10	11	12	13	14

Table 47. HFE Correlatioon Matrix for Type of Usability Information - After The Code Has Been Written

Boxes with double-lined borders indicate p <= 0.0006.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Type of user errors	1	1													
		0													
Frequency of user errors	2	0.77776	1												
		0.0001	0												
Number of user errors	3	0.68054	0.91304	1											
		0.0001	0.0001	0											
Time for user to recover from an error	4	0.40935	0.43358	0.52993	1										
		0.0247	0.0167	0.0026	0										
Reacquisition of skills after time away from the software	5	0.28221	0.22537	0.13522	0.2697	1									
		0.1308	0.2311	0.4762	0.1495	0									
Motivation to use the software	6	0.23959	0.24727	0.24727	0.21919	0.54687	1								
		0.2022	0.1877	0.1877	0.2445	0.0018	0								
User productivity	7	0.37708	0.45991	0.38326	0.22083	0.28607	0.66842	1							
		0.04	0.0106	0.0366	0.2409	0.1254	0.0001	0							
Team member's opinion	8	-0.2256	-0.3784	-0.3784	-0.0093	0.2092	0.14345	0.08894	1						
		0.2306	0.0392	0.0392	0.961	0.2672	0.4495	0.6402	0						
User representative's opinion	9	-0.3346	-0.3401	-0.4761	-0.0452	0.23972	0.05157	0.19184	0.71022	1					
		0.0707	0.066	0.0078	0.8125	0.202	0.7867	0.3098	0.0001	0					
Designs of competitors	10	-0.0788	-0.0587	-0.0587	0.01302	0.37757	0.24499	0.18641	-0.0341	0.20215	1				
		0.6789	0.7578	0.7578	0.9456	0.0397	0.1919	0.324	0.8581	0.284	0				
Guidelines developed by human factors experts	11	0.30343	0.22617	0	0.07518	0.42204	0.23581	0.17943	0.29523	0.28302	-0.0306	1			
		0.1031	0.2295	1	0.693	0.0202	0.2097	0.3428	0.1132	0.1297	0.8727	0			
Data from studies conducted on similar prod. or features	12	0.45796	0.48975	0.40071	0.41769	0.54466	0.57394	0.48666	-0.1464	-0.0139	0.20452	0.25476	1		
		0.0109	0.006	0.0282	0.0216	0.0019	0.0009	0.0064	0.4402	0.9418	0.2783	0.1743	0		
Data from a market research project	13	0.22927	0.28481	0.17089	0.34083	0.20078	0.25916	0.16068	-0.0661	-0.0535	0.01539	0.08889	0.45498	1	
		0.223	0.1271	0.3666	0.0653	0.2874	0.1667	0.3963	0.7286	0.779	0.9357	0.6404	0.0115	0	
Data from a study conducted with representative users	14	0.50473	0.63203	0.54174	0.56692	0.37442	0.34233	0.47754	-0.2183	0	0.12199	0.23483	0.58557	0.47316	1
		0.0044	0.0002	0.002	0.0011	0.0415	0.0641	0.0076	0.2466	1	0.5208	0.2116	0.0007	0.0083	0

Table 48. HFE Correlation Matrix for Type of Usability Information - The Product Has Been Shipped

Boxes with double-lined borders indicate p <= 0.0006.

Type of user errors	1	1 0													
Frequency of user errors	2	0.76047 0.0001	1 0												
Number of user errors	3	0.74634 0.0001	0.95961 0.0001	1 0											
Time for user to recover from an error	4	0.65497 0.0001	0.56632 0.0011	0.6052 0.0004	1 0										
Reacquisition of skills after time away from the software	5	0.39416 0.0311	0.49362 0.0056	0.51158 0.0039	0.46125 0.0103	1 0									
Motivation to use the software	6	0.19506 0.3016	0.42749 0.0185	0.45647 0.0112	0.2663 0.1549	0.72928 0.0001	1 0								
User productivity	7	0.501 0.0048	0.43921 0.0152	0.49656 0.0053	0.52233 0.0031	0.46829 0.0091	0.64889 0.0001	1 0							
Team member's opinion	8	-0.0634 0.7394	-0.2222 0.2379	-0.157 0.4073	0.04719 0.8044	0.05923 0.7559	0.1026 0.5895	0.31623 0.0887	1 0						
User representative's opinion	9	0.02969 0.8762	-0.1562 0.4099	-0.1635 0.388	0.09581 0.6145	0.27753 0.1376	0.20029 0.2886	0.24693 0.1883	0.46852 0.009	1 0					
Designs of competitors	10	-0.3363 0.0692	-0.2722 0.1457	-0.2137 0.2569	-0.2505 0.1819	0.24183 0.1979	0.20943 0.2667	-0.1076 0.5715	0.40825 0.0251	0.09564 0.6152	1 0				
Guidelines developed by human factors experts	11	0.19801 0.2942	0.15189 0.423	0.2385 0.2044	0.27034 0.1485	0.11568 0.5427	0.03339 0.8609	0.30877 0.0969	0.13019 0.4929	0.11183 0.5563	0.1063 0.5761	1 0			
Data from studies conducted on similar prod. or features	12	0.29202 0.1174	0.26548 0.1562	0.31265 0.0925	0.37854 0.0391	0.35382 0.0551	0.43774 0.0156	0.44974 0.0126	0.17066 0.3672	0.10661 0.575	0.06967 0.7145	0.15553 0.4118	1 0		
Data from a market research project	13	0.1547 0.4143	0.05812 0.7603	0.12169 0.5218	0.4718 0.0085	0.41315 0.0233	0.11927 0.5302	0.0919 0.6291	0.2325 0.2163	0.26325 0.1599	0.26102 0.1636	0.16648 0.3793	0.35711 0.0527	1 0	
Data from a study conducted with representative users	14	0.35568 0.0537	0.24499 0.1919	0.24481 0.1923	0.58019 0.0008	0.47494 0.008	0.23993 0.2016	0.31693 0.0879	0.13363 0.4814	0.24 0.2014	0.05455 0.7746	0.16527 0.3828	0.59295 0.0006	0.5903 0.0006	1 0
		1	2	3	4	5	6	7	8	9	10	11	12	13	14

Table 49. Summary of HFE Correlation Matrices for Type of Usability Information

Boxes with double-lined borders indicate p <= 0.0006 for four points in development.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Type of user errors	1														
Frequency of user errors	2	4													
Number of user errors	3	3	4												
Time for user to recover from an error	4	3	2	3											
Reacquisition of skills after time away from the software	5	1		1											
Motivation to use the software	6					1									
User productivity	7					1	4								
Team member's opinion	8														
User representative's opinion	9								2						
Designs of competitors	10								1						
Guidelines developed by human factors experts	11				1										
Data from studies conducted on similar product or features	12														
Data from a market research project	13												1		
Data from a study conducted with representative users	14												3	2	

Table 50. SD Correlation Matrix for Type of Usability Information - No Code Has Been Written

Boxes with double-lined borders indicate p <= 0.0006.

Type of user errors	1	1													
		0													
Frequency of user errors	2	0.47803	1												
		0.0075	0												
Number of user errors	3	0.49817	0.8995	1											
		0.0051	0.0001	0											
Time for user to recover	4	0.38133	0.47926	0.48558	1										
from an error		0.0376	0.0074	0.0065	0										
Reacquisition of skills after	5	0.19679	0.33003	0.31394	0.69608	1									
time away from the software		0.2973	0.0749	0.0911	0.0001	0									
Motivation to use the	6	0.12555	0.13346	0.19932	0.51494	0.69355	1								
software		0.5086	0.482	0.291	0.0036	0.0001	0								
User productivity	7	0.47995	0.39848	0.26031	0.47674	0.53035	0.37321	1							
		0.0073	0.0292	0.1647	0.0077	0.0026	0.0422	0							
Team member's opinion	8	0.06972	0.10413	0.02498	0.02901	0.1344	0.12083	0.13782	1						
		0.7143	0.584	0.8957	0.879	0.4789	0.5248	0.4677	0						
User representative's opinion	9	0.04404	0.19839	0.21796	0.3505	0.35155	0.4905	0.3505	0.02429	1					
		0.8173	0.2933	0.2472	0.0576	0.0568	0.0059	0.0576	0.8986	0					
Designs of competitors	10	-0.1019	0.02782	-0.0517	0.14017	0.06659	0.34982	0.14017	0.41221	0.08942	1				
		0.5921	0.884	0.786	0.46	0.7266	0.0581	0.46	0.0236	0.6384	0				
Guidelines developed by	11	0.17616	-0.1082	-0.0503	0.13631	-0.074	0.22152	0.03894	-0.1458	0.19565	0.02236	1			
human factors experts		0.3518	0.5692	0.7918	0.4726	0.6975	0.2394	0.8381	0.4421	0.3001	0.9067	0			
Data from studies conducted	12	-0.1762	-0.0721	-0.2012	-0.1363	-0.2035	0.01582	-0.1363	0.26723	0.02174	0.42475	0.30435	1		
on similar prod. or features		0.3518	0.7048	0.2864	0.4726	0.2807	0.9339	0.4726	0.1534	0.9092	0.0193	0.102	0		
Data from a market research	13	-0.2595	-0.0654	-0.1064	0.05294	-0.1006	0.22945	-0.1235	0.13211	0.11822	0.48626	0.37435	0.80781	1	
project		0.1662	0.7314	0.5759	0.7811	0.5968	0.2226	0.5154	0.4865	0.5338	0.0064	0.0415	0.0001	0	
Data from a study conducted	14	-0.3019	-0.146	-0.2548	-0.1029	0.21088	0.23783	0.09006	0.1244	0.12927	0.25479	0.1939	0.56017	0.50769	1
with representative users		0.1049	0.4415	0.1742	0.5884	0.2633	0.2057	0.636	0.5125	0.496	0.1742	0.3046	0.0013	0.0042	0
		1	2	3	4	5	6	7	8	9	10	11	12	13	14

Table 51. SD Correlation Matrix for Type of Usability Information - The Code Is Being Written

Boxes with double-lined borders indicate p <= 0.0006.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Type of user errors	1	1													
		0													
Frequency of user errors	2	0.58091	1												
		0.0008	0												
Number of user errors	3	0.34227	0.70219	1											
		0.0641	0.0001	0											
Time for user to recover	4	0.34458	0.64464	0.48651	1										
from an error		0.0622	0.0001	0.0064	0										
Reacquisition of skills after	5	0.28476	0.43942	0.30272	0.68254	1									
time away from the software		0.1272	0.0151	0.1039	0.0001	0									
Motivation to use the	6	0.21938	0.20905	0.12114	0.45042	0.48507	1								
software		0.2441	0.2676	0.5237	0.0125	0.0066	0								
User productivity	7	0.40949	0.42871	0.10941	0.3943	0.3943	0.39315	1							
		0.0246	0.0181	0.5649	0.0311	0.0311	0.0316	0							
Team member's opinion	8	0.30151	0.15211	0.07568	0.11111	0.11111	-0.0809	0.33588	1						
		0.1054	0.4223	0.691	0.5589	0.5589	0.6711	0.0696	0						
User representative's opinion	9	0.19785	0.03932	-0.2573	0.19601	0.23862	0.01447	0.26397	0.2585	1					
		0.2946	0.8366	0.1698	0.2992	0.2041	0.9395	0.1587	0.1678	0					
Designs of competitors	10	0.21386	-0.052	-0.0895	-0.0338	-0.0525	0.21026	0.0656	0.18389	0.08933	1				
		0.2565	0.7851	0.6383	0.8594	0.7827	0.2648	0.7305	0.3307	0.6388	0				
Guidelines developed by	11	0.36802	0.2004	0.29032	0.31553	0.42624	0.45111	0.11714	-0.0388	0.1595	0.06413	1			
human factors experts		0.0454	0.2883	0.1196	0.0894	0.0188	0.0123	0.5376	0.8389	0.3998	0.7364	0			
Data from studies conducted	12	-0.0973	0	0.08793	0.18443	0.21517	0.2818	0	-0.2152	0.11552	0	0.33767	1		
on similar prod. or features		0.609	1	0.644	0.3292	0.2535	0.1314	1	0.2535	0.5433	1	0.068	0		
Data from a market research	13	-0.2557	-0.2634	-0.1203	0.16657	0.318	0.2828	-0.1068	-0.318	0.23397	-0.0585	0.01232	0.6158	1	
project		0.1727	0.1597	0.5265	0.379	0.0868	0.13	0.5743	0.0868	0.2134	0.7589	0.9485	0.0003	0	
Data from a study conducted	14	0.04029	0.0542	0.03034	0.34362	0.3118	0.35651	0.26931	0.13363	0.48628	0.14744	0.20195	0.38816	0.45327	1
with representative users		0.8326	0.776	0.8736	0.063	0.0935	0.0531	0.1501	0.4814	0.0064	0.4369	0.2845	0.034	0.0119	0

Table 52. SD Correlation Matrix for Type of Usability Information - After The Code Has Been Written

Boxes with double-lined borders indicate p <= 0.0006.

Type of user errors	1	1													
		0													
Frequency of user errors	2	0.32784	1												
		0.077	0												
Number of user errors	3	0.32882	0.70474	1											
		0.076	0.0001	0											
Time for user to recover from an error	4	0.15587	0.54051	0.3728	1										
		0.4108	0.002	0.0425	0										
Reacquisition of skills after time away from the software	5	0.0403	0.02892	-0.1021	-0.0699	1									
		0.8325	0.8794	0.5915	0.7136	0									
Motivation to use the software	6	0.33719	0.20776	0.16725	0.31712	0.22551	1								
		0.0684	0.2706	0.377	0.0877	0.2308	0								
User productivity	7	0.212	0.40562	0.15908	0.36761	0.19012	0.55714	1							
		0.2607	0.0262	0.4011	0.0457	0.3143	0.0014	0							
Team member's opinion	8	-0.0375	-0.251	-0.1687	-0.104	-0.1344	-0.1906	-0.2357	1						
		0.8441	0.181	0.3728	0.5845	0.4788	0.313	0.2099	0						
User representative's opinion	9	0.4326	0.00351	-0.0949	0.178	0.09205	0.27598	0.25363	-0.0978	1					
		0.017	0.9853	0.6179	0.3467	0.6285	0.1399	0.1763	0.6071	0					
Designs of competitors	10	-0.0071	0.0542	0.08769	-0.1965	0.02541	-0.0576	0.02227	-0.0945	-0.2126	1				
		0.9704	0.776	0.645	0.298	0.894	0.7622	0.907	0.6194	0.2594	0				
Guidelines developed by human factors experts	11	0.09269	-0.0443	-0.1244	-0.0247	-0.0128	0.21035	0.04484	0.09513	0.33967	0.12585	1			
		0.6261	0.816	0.5125	0.8968	0.9465	0.2645	0.814	0.617	0.0663	0.5076	0			
Data from studies conducted on similar prod. or features	12	0.09915	-0.2507	-0.1515	-0.0491	0.27946	0.15851	-0.0891	0.33072	0.0647	0.0625	0.26068	1		
		0.6022	0.1815	0.4243	0.7966	0.1348	0.4028	0.6397	0.0743	0.7341	0.7428	0.1641	0		
Data from a market research project	13	0.17706	-0.1301	-0.0036	-0.1535	0.21549	0.09006	-0.0597	0.21091	0.17744	-0.008	0.4053	0.70948	1	
		0.3493	0.4933	0.9851	0.418	0.2528	0.636	0.7542	0.2632	0.3482	0.9667	0.0263	0.0001	0	
Data from a study conducted with representative users	14	0.03311	-0.0158	0.00932	-0.1148	0.02969	-0.1095	0.28632	-0.0552	0.18365	0.02087	0.04202	0.17739	0.45651	1
		0.8621	0.9338	0.961	0.5457	0.8762	0.5647	0.1251	0.772	0.3313	0.9128	0.8255	0.3483	0.0112	0
		1	2	3	4	5	6	7	8	9	10	11	12	13	14

Table 53. SD Correlation Matrix for Type of Usability Information - The Product Has Been Shipped

Boxes with double-lined borders indicate p <= 0.0006.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Type of user errors	1	1													
		0													
Frequency of user errors	2	0.53704	1												
		0.0022	0												
Number of user errors	3	0.5618	0.5618	1											
		0.0012	0.0012	0											
Time for user to recover from an error	4	0.15696	0.15696	0.21865	1										
		0.4075	0.4075	0.2457	0										
Reacquisition of skills after time away from the software	5	0.31524	0.31524	0.39848	0.48243	1									
		0.0897	0.0897	0.0292	0.0069	0									
Motivation to use the software	6	0.26919	0.26919	0.19444	0.48891	0.7001	1								
		0.1503	0.1503	0.3032	0.0061	0.0001	0								
User productivity	7	0.27783	0.35955	0.2479	0.44853	0.68007	0.7127	1							
		0.1371	0.051	0.1866	0.0129	0.0001	0.0001	0							
Team member's opinion	8	0	0.29617	-0.107	0.17931	-0.2101	-0.0478	-0.0871	1						
		1	0.112	0.5737	0.3431	0.2652	0.8018	0.6471	0						
User representative's opinion	9	0.03721	0.31628	0.08063	-0.0338	0.3563	0.13522	0.18061	0.04959	1					
		0.8452	0.0886	0.6719	0.8593	0.0533	0.4762	0.3395	0.7947	0					
Designs of competitors	10	-0.0434	0.17359	0.02351	0.0613	0.02052	0.21027	0.20426	-0.1157	0.41419	1				
		0.8199	0.359	0.9019	0.7476	0.9143	0.2647	0.2789	0.5427	0.0229	0				
Guidelines developed by human factors experts	11	0.25363	0.13834	0.04996	0.10702	0.23441	0.16758	0.29844	0.06146	0.24323	0.27917	1			
		0.1763	0.466	0.7932	0.5735	0.2125	0.3761	0.1092	0.747	0.1953	0.1352	0			
Data from studies conducted on similar prod. or features	12	0.11785	0.11785	0.12769	0.19026	0.44582	0.34262	0.27735	-0.1257	0.3552	0.04603	0.48912	1		
		0.5351	0.5351	0.5013	0.3139	0.0135	0.0638	0.1378	0.5082	0.0541	0.8091	0.0061	0		
Data from a market research project	13	0.03977	-0.0597	-0.1293	0.16453	0.14575	0.24088	0.22229	-0.053	0.16981	0.28736	0.59008	0.67492	1	
		0.8347	0.7542	0.496	0.385	0.4422	0.1997	0.2378	0.7809	0.3697	0.1236	0.0006	0.0001	0	
Data from a study conducted with representative users	14	0.34151	0.34151	0.02846	-0.0053	0.11801	0.19094	0.47914	-0.07	0.03959	0.28729	0.41976	0.05573	0.27739	1
		0.0647	0.0647	0.8813	0.9778	0.5345	0.3122	0.0074	0.7131	0.8355	0.1237	0.0209	0.7699	0.1378	0

Table 54. Summary of SD Correlation Matrices for Type of Usability Information

Boxes with double-lined borders indicate p <= 0.0006 for four points in development.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Type of user errors	1														
Frequency of user errors	2														
Number of user errors	3		3												
Time for user to recover from an error	4		1												
Reacquisition of skills after time away from the software	5				2										
Motivation to use the software	6					2									
User productivity	7					1	1								
Team member's opinion	8														
User representative's opinion	9														
Designs of competitors	10														
Guidelines developed by human factors experts	11														
Data from studies conducted on similar product or features	12														
Data from a market research project	13											1	4		
Data from a study conducted with representative users	14														

Analyses of Variance

Table 55 contains the ANOVA summary table for the type of usability information. Using α = 0.05, all effects except the three-way interaction were statistically significant. The two-way interactions were analyzed using simple-effect F tests.

Education x type of usability information interaction. Table 56 contains the ANOVA summary table for the simple-effect analysis for the education x type of usability information interaction. The analysis resulted in education being statistically significant (α = 0.05) in 9 of the 14 types of usability information:

- Type of user errors (u_1)
- Frequency of user errors (u_2)
- Time for user to recover from an error (u_4)
- Reacquisition of skills after time away from the software (u_5)
- Motivation to use the software (u_6)
- User productivity (u_7)
- Guidelines developed by human factors experts (u_{11})
- Data from studies conducted on similar products or product features (u_{12})
- Data from a study conducted with representative users (u_{14})

For each of the types of usability information, HFEs indicated that the product should be changed more often than the SDs (Table 57).

Education x point in development interaction. Table 58 contains the ANOVA summary table for the simple-effect analysis for the education x point in development interaction. The analysis resulted in education being statistically significant (α = 0.05) in three of the four points in development. In each of these, HFEs indicated that the product should be changed more often than the SDs (Table 59).

Table 55. ANOVA Summary Table for the Usability Information

Source	*df*	*SS*	*MS*	*F*	ϵ^a	*P*
Between						
Education	1	50.03	50.03	17.84	--	0.0001
S/E	58	162.64	2.80			
Within						
Usability Information (U)	13	137.25	10.56	19.05	0.568	0.0000
U x E	13	17.74	1.36	2.46	0.568	0.0156
U x S/E	754	417.88	0.55		0.568	
Point in Development (D)	3	259.54	86.52	108.05	0.651	0.0000
D x E	3	12.42	4.14	5.17	0.651	0.0075
D x S/E	174	139.32	0.80		0.651	
U x D	39	11.20	0.29	1.81	0.416	0.0251
U x D x E	39	6.21	0.16	1.01	0.416	0.4434
U x D x S/E	2258[b]	358.30	0.16		0.416	
Total	3355	1572.53				

[a] Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959).

[b] Four ratings that were omitted were replaced with the mean of the cell, therefore reducing the degrees of freedom by four.

Table 56. Simple-Effect F Tests for the Education (E) x Type of Usability Information (u_i) Interaction

Source	*df*	*SS*	*MS*	*F*	*p*[a]
E @ Type of user errors(u_1)	1	7.35	7.35	13.26	0.0003
E @ Frequency of user errors(u_2)	1	7.35	7.35	13.26	0.0003
E @ Number of user errors(u_3)	1	11.70	11.70	3.75	0.0802
E @ Time for user to recover from an error(u_4)	1	4.08	4.08	7.37	0.0069
E @ Reacquisition of skills after time away from the software(u_5)	1	6.02	6.02	10.86	0.0011
E @ Motivation to use the software(u_6)	1	2.60	2.60	4.70	0.0307
E @ User productivity(u_7)	1	2.82	2.82	6.08	0.0247
E @ Team member's opinion(u_8)	1	0.07	0.07	0.12	0.7289
E @ User representative's opinion(u_9)	1	0.70	0.70	1.27	0.2603
E @ Designs of competitors(u_{10})	1	0.94	0.94	1.69	0.1941

[a] Probability determined using a Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959) to adjust the *df*s for the error term (ϵ = 0.568).

Table 56 (Continued). Simple-Effect F Tests for the Education (E) x Type of Usability Information (u_i) Interaction

Source	*df*	*SS*	*MS*	*F*	P^a
E @ Guidelines developed by human factors experts(u_{11})	1	9.20	9.20	16.61	0.0001
E @ Data from studies conducted on similar products or product features(u_{12})	1	5.10	5.10	9.21	0.0026
E @ Data from a market research project(u_{13})	1	1.84	1.84	3.32	0.693
E @ Data from a study conducted with representative users(u_{14})	1	8.07	8.07	14.56	0.0002
U x S/E	754	417.88	0.55		

[a] Probability determined using a Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959) to adjust the *df*s for the error term (ϵ = 0.568).

Table 57. Summary for the Education x Type of Usability Information Interaction

Type of Usability Information	*Education*	*Statistics* Mean	Standard Error
Type of user errors (u_1)	HFE	1.42	0.05
	SD	1.78	0.06
Frequency of user errors (u_2)	HFE	1.47	0.06
	SD	1.83	0.07
Time for user to recover from an error (u_4)	HFE	1.73	0.06
	SD	1.99	0.06
Reacquisition of skills after time away from the software (u_5)	HFE	2.08	0.06
	SD	2.39	0.06
Motivation to use the software (u_6)	HFE	2.02	0.06
	SD	2.23	0.07
User productivity (u_7)	HFE	1.71	0.06
	SD	1.92	0.07
Guidelines developed by human factors experts (u_{11})	HFE	1.71	0.05
	SD	2.10	0.07
Data from studies conducted on similar products or product features (u_{12})	HFE	1.89	0.06
	SD	2.18	0.06
Data from a study conducted with representative users (u_{14})	HFE	1.55	0.06
	SD	1.92	0.05

Table 58. Simple-Effect F Tests for the Education (E) x Point in Developmentü (d_i) Interaction

Source	*df*	*SS*	*MS*	*F*	P^a
E @ No code has been written (d_1)	1	.87	.87	1.08	0.3004
E @ Code is being written (d_2)	1	10.08	10.08	12.58	0.0006
E @ After the code has been written (d_3)	1	33.20	33.20	41.47	0.0000
E @ Product has been shipped (d_4)	1	18.30	18.30	22.86	0.0000
D x S/E	174	139.32	0.80		

[a] Probability determined using a Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959) to adjust the *df*s for the error term (ϵ = 0.651).

Table 59. Summary for the Education x Point in Development Interaction

		Statistics	
Point in Development	*Education*	*Mean*	*Standard Error*
Code is being written (d_2)	HFE	1.70	0.03
	SD	1.92	0.03
After the code has been written (d_3)	HFE	1.89	0.03
	SD	2.28	0.03
Product has been shipped (d_4)	HFE	2.14	0.03
	SD	2.43	0.03

Point in development x type of usability information interaction. Table 60 contains the ANOVA summary table for the simple-effect analysis for the point in development x type of usability information interaction. The analysis resulted in point in development being statistically significant (α = 0.05) for all the types of usability information. Table 61 is a summary of the results of the Newman-Keuls post-hoc analysis.

Education. The significance of the main effect of education showed that HFEs (mean = 1.81, standard error = 0.02) would change the product more often that SDs (mean = 2.05, standard error = 0.02).

Type of usability information. The main effect of type of usabilty information was analyzed using the Newman-Keuls post-hoc test. Table 62 contains the results of this analysis.

Point in development. The main effect of point in development was analyzed using the Newman-Keuls post-hoc test. Table 63 contains the results of this analysis.

Table 60. Simple-Effect F Tests for the Point in Development (D) x Type of Usability Information (u_i) Interaction

Source	*df*	*SS*	*MS*	*F*	*p*[a]
D @ Type of user errors(u_1)	3	13.50	4.50	28.36	0.0000
D @ Frequency of user errors(u_2)	3	15.23	5.08	32.00	0.0000
D @ Number of user errors(u_3)	3	15.68	5.23	32.94	0.0000
D @ Time for user to recover from an error(u_4)	3	19.35	6.45	40.64	0.0000
D @ Reacquisition of skills after time away from the software(u_5)	3	23.60	7.87	49.58	0.0000
D @ Motivation to use the software(u_6)	3	19.75	6.58	41.48	0.0000
D @ User productivity(u_7)	3	17.67	5.89	37.11	0.0000
D @ Team member's opinion(u_8)	3	18.68	6.23	39.25	0.0000
D @ User representative's opinion(u_9)	3	7.38	2.46	15.50	0.0000
D @ Designs of competitors(u_{10})	3	20.05	6.68	42.11	0.0000

[a] Probability determined using a Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959) to adjust the degrees of freedom. Epsilon for *df* for the numerator = 0.6510 and epsilon for the *df* for denominator = 0.4156

Table 60 (Continued). Simple-Effect F Tests for the Point in Development (D) x Type of Usability Information (u_i) Interaction

Source	*df*	*SS*	*MS*	*F*	*P*[a]
D @ Guidelines developed by human factors experts(u_{11})	3	30.65	10.22	64.38	0.0000
D @ Data from studies conducted on similar products or product features(u_{12})	3	30.05	10.02	63.12	0.0000
D @ Data from a market research project(u_{13})	3	22.61	7.54	47.50	0.0000
D @ Data from a study conducted with representative users(u_{14})	3	16.57	5.52	34.80	0.0000
D x U x S/E	2258	358.30	0.16		

[a] Probability determined using a Greenhouse-Geisser epsilon (Greenhouse and Geisser, 1959) to adjust the degrees of freedom. Epsilon for *df* for the numerator = 0.6510 and epsilon for the *df* for denominator = 0.4156

Table 61. Summary for the Type of Usability Information x Point in Development Interaction

Type of Usability Information	*Point in Development*[a]	*Mean*	*Standard Error*	*Grouping*[b]
Type of user errors(u_1)	No code has been written(d_1)	1.32	0.07	A
	Code is being written(d_2)	1.47	0.08	AB
	After the code has been written(d_3)	1.67	0.08	B
	Product has been shipped(d_4)	1.95	0.08	C
Frequency of user errors(u_2)	No code has been written(d_1)	1.35	0.08	A
	Code is being written(d_2)	1.48	0.08	A
	After the code has been written(d_3)	1.77	0.09	B
	Product has been shipped(d_4)	2.00	0.08	C
Number of user errors(u_3)	No code has been written(d_1)	1.43	0.09	A
	Code is being written(d_2)	1.63	0.09	AB
	After the code has been written(d_3)	1.87	0.09	B
	Product has been shipped(d_4)	2.12	0.09	C

[a] Ascending order by value of the means.

[b] Means with the same letter are not significantly different.

Table 61 (Continued). Summary for the Type of Usability Information x Point in Development Interaction

Type of Usability Information	*Point in Development*[a]	*Mean*	*Standard Error*	*Grouping*[b]
Time for user to recover from an error(u_4)	No code has been written(d_1)	1.45	0.08	A
	Code is being written(d_2)	1.80	0.09	B
	After the code has been written(d_3)	1.97	0.07	B
	Product has been shipped(d_4)	2.23	0.08	C
Reacquisition of skills after time away from the software(u_5)	No code has been written(d_1)	1.80	0.09	A
	Code is being written(d_2)	2.10	0.07	B
	After the code has been written(d_3)	2.40	0.08	C
	Product has been shipped(d_4)	2.63	0.07	D
Motivation to use the software(u_6)	No code has been written(d_1)	1.68	0.09	A
	Code is being written(d_2)	2.05	0.09	B
	After the code has been written(d_3)	2.33	0.08	C
	Product has been shipped(d_4)	2.42	0.08	C

[a] Ascending order by value of the means.

[b] Means with the same letter are not significantly different.

Table 61 (Continued). Summary for the Type of Usability Information x Point in Development Interaction

Type of Usability Information	*Point in Development*[a]	*Mean*	*Standard Error*	*Grouping*[b]
User productivity(u_7)	No code has been written(d_1)	1.43	0.08	A
	Code is being written(d_2)	1.70	0.09	A
	After the code has been written(d_3)	2.00	0.09	B
	Product has been shipped(d_4)	2.13	0.09	B
Team member's opinion(u_8)	No code has been written(d_1)	1.78	0.06	A
	Code is being written(d_2)	1.92	0.05	A
	After the code has been written(d_3)	2.23	0.06	B
	Product has been shipped(d_4)	2.50	0.07	C
User representative's opinion(u_9)	No code has been written(d_1)	1.67	0.07	A
	Code is being written(d_2)	1.83	0.07	AB
	After the code has been written(d_3)	2.03	0.06	BC
	Product has been shipped(d_4)	2.12	0.07	C

[a] Ascending order by value of the means.

[b] Means with the same letter are not significantly different.

Table 61 (Continued). Summary for the Type of Usability Information x Point in Development Interaction

Type of Usability Information	*Point in Development*[a]	*Mean*	*Standard Error*	*Grouping*[b]
Designs of competitors(u_{10})	No code has been written(d_1)	1.88	0.06	A
	Code is being written(d_2)	2.15	0.06	AB
	After the code has been written(d_3)	2.38	0.06	B
	Product has been shipped(d_4)	2.67	0.07	C
Guidelines developed by human factors experts(u_{11})	No code has been written(d_1)	1.42	0.07	A
	Code is being written(d_2)	1.73	0.07	B
	After the code has been written(d_3)	2.12	0.08	C
	Product has been shipped(d_4)	2.35	0.07	D
Data from studies conducted on similar products or product features(u_{12})	No code has been written(d_1)	1.57	0.07	A
	Code is being written(d_2)	1.85	0.08	B
	After the code has been written(d_3)	2.25	0.08	C
	Product has been shipped(d_4)	2.48	0.07	D

[a] Ascending order by value of the means.

[b] Means with the same letter are not significantly different.

Table 61 (Continued). Summary for the Type of Usability Information x Point in Development Interaction

Type of Usability Information	*Point in Development*[a]	*Mean*	*Standard Error*	*Grouping*[b]
Data from a market research project(u_{13})	No code has been written(d_1)	1.57	0.08	A
	Code is being written(d_2)	1.97	0.06	B
	After the code has been written(d_3)	2.27	0.07	C
	Product has been shipped(d_4)	2.35	0.07	C
Data from a study conducted with representative users(u_{14})	No code has been written(d_1)	1.37	0.07	A
	Code is being written(d_2)	1.62	0.08	A
	After the code has been written(d_3)	1.90	0.07	B
	Product has been shipped(d_4)	2.05	0.06	B

[a] Ascending order by value of the means.

[b] Means with the same letter are not significantly different.

Table 62. Summary for the Main Effect of Type of Usability Information (u_i)

Type of Usability Information[a]	*Mean*	*Standard Error*	*Grouping*[b]
Type of user errors(u_1)	1.60	0.04	A
Frequency of user errors(u_2)	1.65	0.04	AB
Data from a study conducted with representative users(u_{14})	1.73	0.04	AB
Number of user errors(u_3)	1.76	0.05	AB
User productivity(u_7)	1.82	0.05	AB
Time for user to recover from an error(u_4)	1.86	0.04	AB
Guidelines developed by human factors experts(u_{11})	1.90	0.04	AB
User representative's opinion(u_9)	1.91	0.03	AB
Data from a market research project(u_{13})	2.04	0.04	AB
Data from studies conducted on similar products or product features(u_{12})	2.04	0.04	AB
Team member's opinion(u_8)	2.11	0.03	AB
Motivation to use the software(u_6)	2.12	0.05	AB
Reacquisition of skills after time away from the software(u_5)	2.23	0.04	AB
Designs of competitors(u_{10})	2.27	0.04	B

[a] Ascending order by value of the means.

[b] Means with the same letter are not significantly different.

Table 63. Summary for the Main Effect of Point in Development (d_i)

Point in Development[a]	*Mean*	*Standard Error*	*Grouping*[b]
No code has been written(d_1)	1.55	0.02	A
Code is being written(d_2)	1.81	0.02	AB
After the code has been written(d_3)	2.08	0.02	AB
Product has been shipped(d_4)	2.29	0.02	B

[a] Ascending order by value of the means.

[b] Means with the same letter are not significantly different.

DISCUSSION AND CONCLUSIONS

Background

The results from the background questionnaire indicate that the participants were representative of the SD and HFE professionals that have been newly hired into a software development environment. Thus, the results of the survey reflect the attitudes which these professionals would have upon entering the workplace.

Education

As discussed previously, people with different frames of reference tend to have communication problems (Hunt, 1980). The results of this study indicate that HFEs and SDs have different frames of reference.

Software industry terms. Figure 8 is a summary of the results on the software industry terms using Schramm's communication model (Hunt, 1980). With these differences in knowledge of certain terms, it is no wonder that communication problems exist between HFEs and SDs. As indicated in Figure 8 and reinforced by the demographic data on the classes taken by HFEs and SDs, HFEs tend to know about software development and what it involves. SDs, on the other hand, know very little about human factors engineering. This is supported by the analysis of the three-way interaction (P x A x E). HFEs and SDs rated the importance of the participation of programmers the same in all activities except "define each customer" and "test the prototype." HFEs and SDs rated the importance of the participation of HFEs different in 10 of the activities. The difference in the frames of reference indicates that,

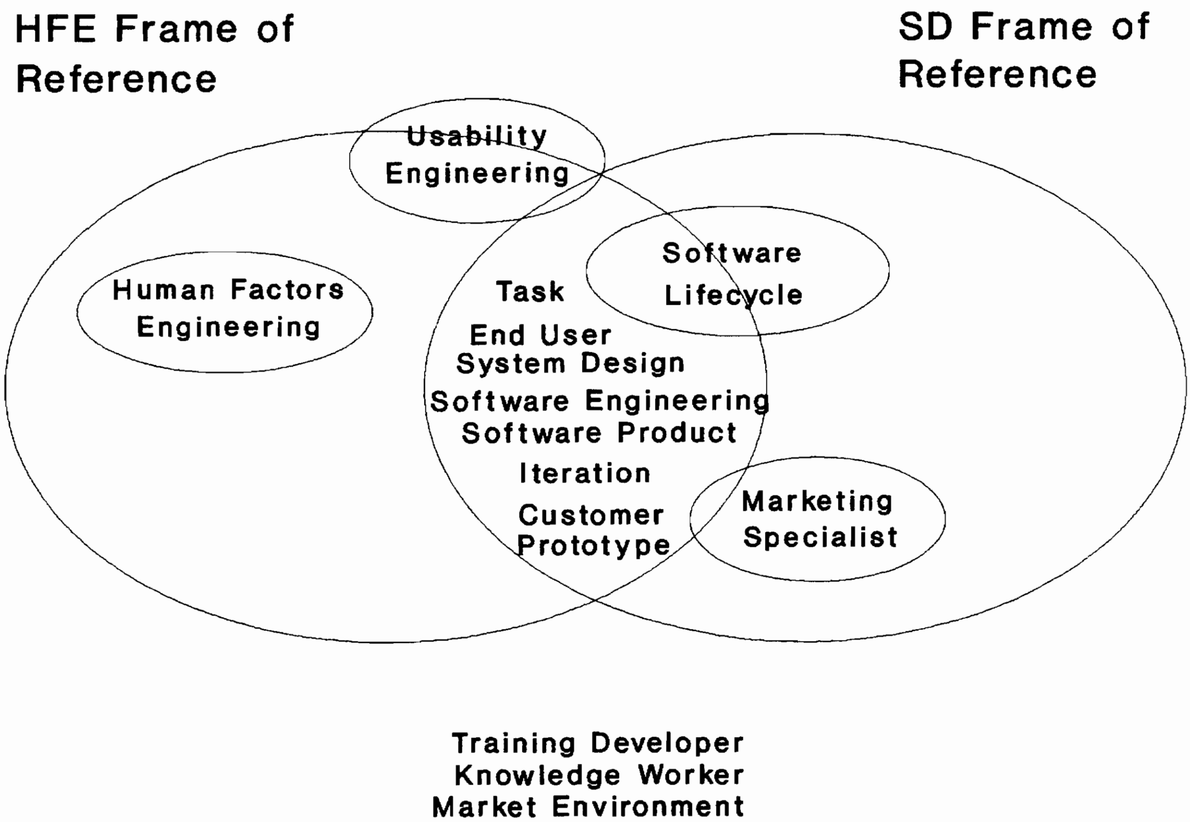

Figure 8. Communication model for software industry terms.

upon entering the workplace, HFEs and SDs could communicate about the SDs' tasks or activities, but not about the HFEs' tasks or activities. In addition, when HFEs and SDs indicate that they have the same amount of knowledge, it does not imply that their level of knowledge about a term is equivalent. Thus, it would be beneficial to software development companies to cross-train HFEs and SDs in these areas when they are hired. The cross-training would ensure that employees would have the same operating definition of all the terms and concepts.

Software development activities. The results of the analysis of the three-way interaction (P x A x E) (Table 36) indicate that HFEs and SDs do not agree on the importance of participation of certain product team members in specific activities. The difference in ratings was especially apparent for the importance of participation of human factors engineers. HFEs rated the importance of their participation higher than SDs in 11 of the 12 activities that were statistically significant (Table 34). Even though these differences in ratings may be influenced by two factors -- inflation of HFE ratings, and the SDs lack of knowledge about human factors engineering -- these differences may account for a lack of communication between HFEs and SDs. HFEs may want to be involved in activities in which SDs don't think HFE involvement is necessarily important.

The results of the two-way interaction (A x E) (Table 40) show that HFEs rated the importance of participating higher than SDs in 12 of the 20 activities. Table 64 indicates the areas in the development of a product where these activities typically occur. Most of these activities are conducted early in the development of the product. Again, this difference in ratings indicates a

Table 64. Product Development Phases

	Planning/ Design	Design Evaluation	Development	Applied Testing
Define each user identified	X			
Determine product requirements	X			
Determine the feasibility of the product	X			
Consider design alternatives	X			
Determine the product design	X			
Develop the prototype		X		
Test the prototype		X		
Develop programs			X	
Develop user training			X	
Test user documentation			X	
Test user training				X
Test product with users				X

potential area for communication problems. Since HFEs believe these activities are more important than SDs, they may want to spend more time or do a more thorough job than SDs believe is important or needed.

Product team members. The analysis of the three-way (P x A x E) (Table 36) and two-way (P x E) (Table 38) interactions for the software development activities questionnaire indicated that HFEs and SDs disagree on the importance of participation of four of the product team members: technical writer, training developer, human factors engineer, and marketing specialist. This difference in ratings indicates that HFEs would involve these people in the project more than an SD. According to the study done by Grudin and Poltrock (1989), technical writers, training developers, human factors engineers, and marketing specialists believe that they get involved in projects too late. They also believe that this late involvement has an impact on the success of the product. Thus, software development companies need to determine when certain professionals should be involved in the development process and then ensure that all employees are trained in this process.

Point in development. HFEs would recommend changing the design of a product later in the development cycle than SDs. This differnce could be a major area of contention between these two professions. Because of this potential problem area, it is recommended that organizations, or at least product teams, set up guidelines prior to the development of the product which indicate how decisions should be made about changing the design of the product. These guidelines would enable members of the product team to know what type of supporting data are needed at different points in the development of the product.

Software Development Activities at Product Team Members

Overall. By examining Table 42 and the importance rating given to each activity in the development process for overall (p_1), it is evident that most of the activities were rated high (mean = 3.82) to very high (mean = 4.75) importance. Only two of the activities -- "meet with the users" and "define each customer identified" -- received average ratings. Considering that there was not a significant difference between the HFE rating and SD rating for "meet with the users," this is a surprising result. Meeting with users is an activity stressed within HFE training. It is also an activity that Gould (1988) stresses most vehemently in his landmark article "How to design usable systems." An average rating for "meet with the users" should be a concern for software companies trying to build usable systems. Meeting with the users is important for knowing what the users need and want. If both HFEs and SDs deem its importance as average, this activity may not receive the attention it deserves and software code may be written before users are contacted. As stated earlier, SDs do not want to change designs as easily if code is already written. Thus, in light of these results, it would benefit software development companies to ensure that users are involved as early as possible in the development process. The early involvement of users would help to prevent debates about changing the design once software code has been written.

Programmers. According to the results of this study, it is less important for programmers to be involved in the early activities of development than the later activities. In light of the fact that SDs do not place as much importance on the early activities as do HFEs, it is likely that SDs will want to spend less time on these activities. It is important for software development companies to assign

SDs to projects at an appropriate time so that they do not rush the early activities of the project. Also, the importance of programmer participation for "meet with the users" was rated low (mean = 2.67) in importance. If the programmer is only there to code a design, then maybe meeting with the users is not important. But, if the programmer is involved with any aspect of designing the product, then Gould (1988) recommends that meetings with the users are necessary. The importance of programmer participation for "develop the prototype" (mean= 4.55) and "test the prototype" (mean = 3.87) are rated high in importance. If the available prototyping tools need programming skills, then programmers may be necessary; if not, then HFEs should play a major role in the development of the prototype. Also, testing the prototype should be conducted by an HFE. Thus, there are some activities which the programmer is assuming which should be performed by the HFE.

Human factors engineers. Even though SDs did not have knowledge of the term human factors engineer, once a definition was provided (Appendix C), they were able to delineate fairly well where the HFE should participate. This ability to delineate HFE participation indicates that if SDs receive training on what human factors engineering is and when it is necessary in a project, they will incorporate the HFEs appropriately.

Type of Usability Information

From the analyses conducted on the data gathered from the usability information questionnaire, it is clear that the desire to change a software product dwindles as the project progresses. The analysis of the main effect of type of usability information (Table 62) indicates that a change is more likely to be made if the supporting information is "type of user errors" rather than "designs of competitors."

Further Research

Further research needs to be conducted in the area of product teams, their composition, and the responsibilities of its members. A step can be made in this direction by modeling a study similar to that of Grudin and Poltrock (1989) using the instrument developed for this thesis.

The software development questionnaire could be expanded by presenting several development environments with different products specified. In addition, if this questionnaire is used in industry, a 7-point rating scale should be used as well as having members from all the professions participate.

The usability information questionnaire could be expanded by asking follow-up questions. For instance, if a person indicated he/she might change the product given a certain type of usability information, a follow-up question could be "how likely are you to change the product based upon the product team member who initiated the change?" This type of information would provide further insight into why design changes may or may not be made.

Summary

The results of this research supported much of the qualitative data (Hammond et al., 1983; Gurdin and Poltrock, 1989; Perrow, 1983) by indicating areas where HFEs and SDs differ in their approach to software development. In light of this research, it is important for software development companies interested in developing usable products to (when bringing in new employees):

- Provide basic training for SDs in human factors engineering indicating when and where HFEs should be involved in the development process.
- Provide guidelines for all product team members for making decisions on design changes.
- Provide training for all product team members on the composition of a product team, the members responsibilities and level of participation in development activities.
- Encourage universities to include human-computer interaction classes at the undergraduate level for SDs.
- Promote recognized methodologies on how to produce usable products within the SD and HFE communities.

By implementing these recommendations, software development companies can improve the lines of communication between HFEs and SDs as well as between other members of the product team. By improving the lines of communication, it is believed that less time will be spent explaining what should be done and more time spent doing it.

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APPENDIX A

HFE BACKGROUND QUESTIONNAIRE

Background Questionnaire
Human Factors

1. Identify your age group by checking the appropriate box.

- ☐ Under 18
- ☐ 18-21
- ☐ 22-24
- ☐ over 24

2. Sex?

- ☐ Male
- ☐ Female

3. In what subject area(s) is your undergraduate degree?

- ☐ Psychology
- ☐ Industrial Engineering
- ☐ Other Engineering
- ☐ Human Factors/Ergonomics
- ☐ Industrial Design
- ☐ Medicine/Physiology/Life Sciences
- ☐ Computer Science
- ☐ Education
- ☐ Business
- ☐ Other

4. Is your undergraduate degree from Virginia Tech?

- ☐ Yes
- ☐ No

5. If you have a masters degree(s), what area is it in?

- ☐ Psychology
- ☐ Industrial Engineering
- ☐ Other Engineering
- ☐ Human Factors/Ergonomics
- ☐ Industrial Design
- ☐ Medicine/Physiology/Life Sciences
- ☐ Computer Science
- ☐ Education
- ☐ Business
- ☐ Other

6. Is your masters degree from Virginia Tech?

☐ Yes

☐ No

7. Are you currently working toward a masters or Ph.D. in human factors?

☐ Masters

☐ Ph.D.

8. In what area of human factors do you plan to work when you obtain the degree you are currently pursuing?

☐ Human computer interaction

☐ Ergonomics

☐ Visual displays

☐ Safety

☐ Hardware design (i.e., computers, cars)

☐ Audition

☐ Professor in HFE

☐ Pursue a Ph.D.

9. Check the computer courses you have taken.

☐ Programming

☐ Operating systems

☐ Systems design

☐ Data bases

☐ Other, please specify

____

____

____

10 Do you have any experience in software design outside the university setting?

☐ Yes

☐ No

If yes, briefly describe your experience.

11. The following terms are used in the software industry. Please check the box which best describes your knowledge of the term.

	No Knowledge	Very Little Knowledge	Moderate Amount of Knowledge	Full Applied Knowledge
Human factors engineering				
End user				
Customer				
Training Developer				
Marketing specialist				
Knowledge worker				
Market environment				
Prototype				
Software product				
Iteration				
Task				
Usability				
Software lifecycle				
Systems design				
Software engineering				
Usability engineering				

APPENDIX B

SD BACKGROUND QUESTIONNAIRE

Background Questionnaire
Computer Science

1. Identify your age group by checking the appropriate box.

   - ☐ Under 18
   - ☐ 18-21
   - ☐ 22-24
   - ☐ over 24

2. Sex?

   - ☐ Male
   - ☐ Female

3. Which of the following classes have you taken, or are currently taking?

- [ ] Introduction to Computer Science
- [ ] Assembly and assemblers
- [ ] Data structures and file management
- [ ] Operating systems
- [ ] Comparative languages
- [ ] Numerical methods
- [ ] Professionalism in computing
- [ ] Foundations of prog. languages and file management
- [ ] Principles of computer architecture and op. systems.
- [ ] Data and algorithm analysis
- [ ] Intro to formal languages and automata theory
- [ ] Theory of computation
- [ ] Computer graphics
- [ ] Simulation and modeling
- [ ] Performance evaluation of computer systems
- [ ] Computer design and implementation
- [ ] Computer organization
- [ ] Intro. to data base management
- [ ] Software engineering
- [ ] Information systems project
- [ ] Intro. to artificial intelligence
- [ ] Human-computer interaction
- [ ] Intro. to human factors engineering

4. Choose, from the following, the type of position you are most interested in upon graduation.

- ☐ Business application programmer (MIS)
- ☐ Data base programmer
- ☐ Operating systems programmer
- ☐ Computing consulting
- ☐ Software design
- ☐ Pursuing a masters degree

5. Do you have any experience in software design outside the university setting?

- ☐ Yes
- ☐ No

If yes, briefly describe your experience.

6. The following terms are used in the software industry. Please check the box which best describes your knowledge of the term.

	No Knowledge	Very Little Knowledge	Moderate Amount of Knowledge	Full Applied Knowledge
Human factors engineering				
End user				
Customer				
Training Developer				
Marketing specialist				
Knowledge worker				
Market environment				
Prototype				
Software product				
Iteration				
Task				
Usability				
Software lifecycle				
Systems design				
Software engineering				
Usability engineering				

APPENDIX C

SOFTWARE DEVELOPMENT ACTIVITIES QUESTIONNAIRE

Software Development Environment

SoftTech, Inc. is a company which develops a variety of software applications. You have been hired to be a member of a software development team. This team consists of:

Programmer(s) - person who writes software

Technical writer(s) - person who writes user documentation

Training developer(s) - person who develops user training

Human factors engineer(s) - person with knowledge in psychology, physiology, engineering, and statistics who works with human machine iterface issues

Marketing specialist(s) - person who conducts business and market analyses

This team is responsible for developing an application which will be sold to members of the Fortune 500 (the customers). The software will have several different types of users, e.g., network managers, operators, secretaries, programmers.

The team has identified 20 activities that need to be performed.

Instructions:

For this portion of the study, you will be answering questions related to these activities.

1. Rate, by a check mark, the importance you feel each of the following activities has to the success of the product.

	Very Low Importance	Low Importance	Average Importance	High Importance	Very High Importance
Identify who the users will be (e.g., programmers, secretaries)					
Define each user identified (e.g., level of education, computer sophistication)					
Meet with the users					
Identify who the customers will be (e.g., manufacturing, insurance)					
Define each customer identified (e.g., number of employees, size of revenue)					
Determine product requirements (i.e., users, market, customers, what the product should allow the customers to do)					
Define the market the product will be sold into					
Determine the feasibility of the product					
Consider design alternatives					
Determine the user interface design					
Determine the product design					
Develop the prototype					
Test the prototype					
Develop programs					
Develop user documentation					
Develop user training					
Test software (functionality, reliability)					
Test user documentation					
Test user training					
Test product with users					

Instructions:

For questions 2-7, determine how important it is for each member of the software development team to PARTICIPATE in each of the activities.

2. Rate, by a check mark, the importance of the PROGRAMMER's participation in the following software development activities.

	Very Low Importance	Low Importance	Average Importance	High Importance	Very High Importance
Identify who the users will be (e.g., programmers, secretaries)					
Define each user identified (e.g., level of education, computer sophistication)					
Meet with the users					
Identify who the customers will be (e.g., manufacturing, insurance)					
Define each customer identified (e.g., number of employees, size of revenue)					
Determine product requirements (i.e., users, market, customers, what the product should allow the customers to do)					
Define the market the product will be sold into					
Determine the feasibility of the product					
Consider design alternatives					
Determine the user interface design					
Determine the product design					
Develop the prototype					
Test the prototype					
Develop programs					
Develop user documentation					
Develop user training					
Test software (functionality, reliability)					
Test user documentation					
Test user training					
Test product with users					

3. Rate, by a check mark, the importance of the TECHNICAL WRITER's participation in the following software development activities.

	Very Low Importance	Low Importance	Average Importance	High Importance	Very High Importance
Identify who the users will be (e.g., programmers, secretaries)					
Define each user identified (e.g., level of education, computer sophistication)					
Meet with the users					
Identify who the customers will be (e.g., manufacturing, insurance)					
Define each customer identified (e.g., number of employees, size of revenue)					
Determine product requirements (i.e., users, market, customers, what the product should allow the customers to do)					
Define the market the product will be sold into					
Determine the feasibility of the product					
Consider design alternatives					
Determine the user interface design					
Determine the product design					
Develop the prototype					
Test the prototype					
Develop programs					
Develop user documentation					
Develop user training					
Test software (functionality, reliability)					
Test user documentation					
Test user training					
Test product with users					

4. Rate, by a check mark, the importance of the TRAINING DEVELOPER's participation in the following software development activities.

	Very Low Importance	Low Importance	Average Importance	High Importance	Very High Importance
Identify who the users will be (e.g., programmers, secretaries)					
Define each user identified (e.g., level of education, computer sophistication)					
Meet with the users					
Identify who the customers will be (e.g., manufacturing, insurance)					
Define each customer identified (e.g., number of employees, size of revenue)					
Determine product requirements (i.e., users, market, customers, what the product should allow the customers to do)					
Define the market the product will be sold into					
Determine the feasibility of the product					
Consider design alternatives					
Determine the user interface design					
Determine the product design					
Develop the prototype					
Test the prototype					
Develop programs					
Develop user documentation					
Develop user training					
Test software (functionality, reliability)					
Test user documentation					
Test user training					
Test product with users					

5. Rate, by a check mark, the importance of the HUMAN FACTORS ENGINEER's participation in the following software development activities.

	Very Low Importance	Low Importance	Average Importance	High Importance	Very High Importance
Identify who the users will be (e.g., programmers, secretaries)					
Define each user identified (e.g., level of education, computer sophistication)					
Meet with the users					
Identify who the customers will be (e.g., manufacturing, insurance)					
Define each customer identified (e.g., number of employees, size of revenue)					
Determine product requirements (i.e., users, market, customers, what the product should allow the customers to do)					
Define the market the product will be sold into					
Determine the feasibility of the product					
Consider design alternatives					
Determine the user interface design					
Determine the product design					
Develop the prototype					
Test the prototype					
Develop programs					
Develop user documentation					
Develop user training					
Test software (functionality, reliability)					
Test user documentation					
Test user training					
Test product with users					

6. Rate, by a check mark, the importance of the MARKETING SPECIALIST's participation in the following software development activities.

	Very Low Importance	Low Importance	Average Importance	High Importance	Very High Importance
Identify who the users will be (e.g., programmers, secretaries)					
Define each user identified (e.g., level of education, computer sophistication)					
Meet with the users					
Identify who the customers will be (e.g., manufacturing, insurance)					
Define each customer identified (e.g., number of employees, size of revenue)					
Determine product requirements (i.e., users, market, customers, what the product should allow the customers to do)					
Define the market the product will be sold into					
Determine the feasibility of the product					
Consider design alternatives					
Determine the user interface design					
Determine the product design					
Develop the prototype					
Test the prototype					
Develop programs					
Develop user documentation					
Develop user training					
Test software (functionality, reliability)					
Test user documentation					
Test user training					
Test product with users					

7. Your team has the opportunity to involve representatives of the user population. It is important that they be brought into the process only when necessary. Therefore, rate the importance of the USER REPRESENTATIVES' participation in each of the 20 activities.

	Very Low Importance	Low Importance	Average Importance	High Importance	Very High Importance
Identify who the users will be (e.g., programmers, secretaries)					
Define each user identified (e.g., level of education, computer sophistication)					
Meet with the users					
Identify who the customers will be (e.g., manufacturing, insurance)					
Define each customer identified (e.g., number of employees, size of revenue)					
Determine product requirements (i.e., users, market, customers, what the product should allow the customers to do)					
Define the market the product will be sold into					
Determine the feasibility of the product					
Consider design alternatives					
Determine the user interface design					
Determine the product design					
Develop the prototype					
Test the prototype					
Develop programs					
Develop user documentation					
Develop user training					
Test software (functionality, reliability)					
Test user documentation					
Test user training					
Test product with users					

APPENDIX D

USABILITY INFORMATION QUESTIONNAIRE

Throughout the development of the software product, changes will be requested by members of the team. The team has identified 14 types of supporting information a team member might have when requesting a change. When the team member requests a change, he/she believes the information is enough to warrant the change.

As a member of the product team, you must determine whether a change should be made to the product. Two things must be considered:

1) the type of supporting information.

2) the point in the development of the software that the change is requested.

Instructions:

For this portion of the study, you will be presented with the 14 types of supporting information. You will also be told the point in the development of the software where the change is being requested. It is your job to rate the 14 types of supporting information according to the following rating scheme:

Change Product - any supporting information of this type would not need further investigation and the product would be changed.

Might Change Product - any supporting information of this type would need further investigation before a decision could be made.

No Change to Product - any supporting information of this type would not need further investigation and the product would not be changed.

1. Indicate, by a check mark, whether the product should be changed for each type of supporting information if NO CODE HAS BEEN WRITTEN.

	Change Product	Might Change Product	NO Change to Product
Type of user errors			
Frequency of user errors			
Number of user errors			
Time for user to recover from an error			
Reacquisition of skills after time away from the software			
Motivation to use the software			
User productivity			
Team member's opinion			
User representative's opinion			
Designs of competitors			
Guidelines developed by human factors experts			
Data from studies conducted on similar products or product features			
Data from a market research project			
Data from a study conducted with representative users			

2. Rate, by a check mark, whether the product should be changed for each type of supporting information if THE CODE IS BEING WRITTEN.

	Change Product	Might Change Product	NO Change to Product
Type of user errors			
Frequency of user errors			
Number of user errors			
Time for user to recover from an error			
Reacquisition of skills after time away from the software			
Motivation to use the software			
User productivity			
Team member's opinion			
User representative's opinion			
Designs of competitors			
Guidelines developed by human factors experts			
Data from studies conducted on similar products or product features			
Data from a market research project			
Data from a study conducted with representative users			

3. Rate, by a check mark, whether the product should be changed for each type of supporting information AFTER THE CODE HAS BEEN WRITTEN.

	Change Product	Might Change Product	NO Change to Product
Type of user errors			
Frequency of user errors			
Number of user errors			
Time for user to recover from an error			
Reacquisition of skills after time away from the software			
Motivation to use the software			
User productivity			
Team member's opinion			
User representative's opinion			
Designs of competitors			
Guidelines developed by human factors experts			
Data from studies conducted on similar products or product features			
Data from a market research project			
Data from a study conducted with representative users			

4. Rate, by a check mark, whether the product should be changed for each type of supporting information if THE PRODUCT HAS BEEN SHIPPED.

	Change Product	Might Change Product	NO Change to Product
Type of user errors			
Frequency of user errors			
Number of user errors			
Time for user to recover from an error			
Reacquisition of skills after time away from the software			
Motivation to use the software			
User productivity			
Team member's opinion			
User representative's opinion			
Designs of competitors			
Guidelines developed by human factors experts			
Data from studies conducted on similar products or product features			
Data from a market research project			
Data from a study conducted with representative users			

APPENDIX E

VERBAL INSTRUCTIONS

Background Questionnaire

Thank you for your participation. The first part of the questionnaire is the Background Questionnaire. This questionnaire is for information on your background and experience.

Please complete the questionnaire by following the instructions. If you have any questions feel free to ask. Remember there may be some questions I will refrain from answering.

Once you have finished the Background Questionnaire, please wait for the others in the room to complete theirs.

Are there any questions?

[If not]

Proceed with completing the background questionnaire. Stop when you reach the RED page.

Software Development Questionnaire

This questionnaire covers two aspects of software development: who should participate in certain software development activities and what type of information is needed for a design change. The questionnaire is divided into two parts which reflect these two aspects.

In a moment, I will ask you to break open the questionnaire and read the description of the software development environment. This description may be removed from the questionnaire for easy reference. Everyone will read the description of the environment and any questions you have will be answered. When all questions have been answered, I will announce that you may begin completing the questionnaire. No one may begin the questionnaire until told to do so.

You will notice a pink page in the questionniare. This page is used to divide the two parts of the questionniare as well as to provide information concerning the second part. If you have any questions after reading this page, please ask me for clarification. This page may be removed from the questionnaire for easy reference.

When you have completed the questionnaire, bring it to me. At that time you will receive payment for your participation.

Are there any questions? If not, break open the questionnaire.

[Questionnaire is opened]

Please follow along with me as I read the description of the hypothetical software development environment.

[Read the description of the software development environment.]

Are there any questions?

Please refer to the description of the software development environment as you complete the first part of the questionnaire. If you have any questions while you are completing the questionnaire, raise your hand and I will come to you and talk to you. Remember, there may be some questions I refuse to answer. When you are finished, check back through the entire questionnaire to ensure that you have not missed any questions. Then, bring the questionnaire to me.

Any further questions?

[If not]

Thanks again for your participation. You may complete the questionnaire.

APPENDIX F

FOLLOW-UP QUESTIONNAIRE

Follow-up Questionnaire

1. Rate the length of the questionnaire

☐ Not long enough

☐ OK

☐ Too long

Please explain your rating.

2. Rate the knowledge level of the questionnaire.

☐ Too difficult

☐ OK

☐ Too easy

Please explain your rating.

3. Are the rating scales used in the questionnaire meaningful? Why or why not?

4. Go back through the attached blank questionnaire and circle any questions or statements that were unclear.

5. What did you think of the administration of the questionnaire. (Check all that apply)

- ☐ Would rather have been alone
- ☐ 3 people is OK
- ☐ More than 3 people would be OK

APPENDIX G

INDUSTRY TERMS CHI-SQUARE SUMMARY TABLES AND FREQUENCY HISTOGRAMS

Table 65. Sutcliffe Chi-Square Summary Table - Human Factors Engineering

Source	*df*	X^2
Education (E)	1	$X^2_E = 0$
Rating (R)	3	$X^2_R = 7.87^*$
ExR	3	$X^2_{ExR} = 52.66^{**}$
Total	7	$X^2_{Total} = 60.53^{**}$

* $0.02 < p < 0.05$

** $p < 0.001$

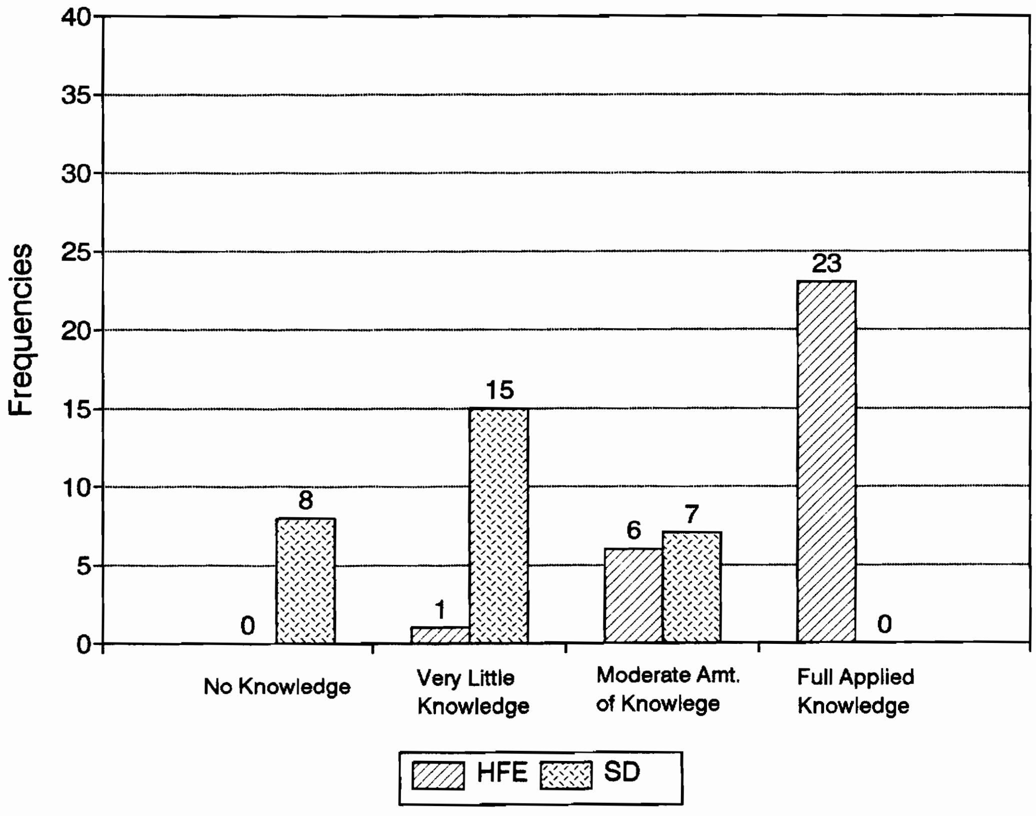

Figure 9. Frequency histogram of software industry term - human factors engineering.

Table 66. Sutcliffe Chi-Square Summary Table - End User

Source	*df*	X^2
Education (E)	1	$X^2_E =$ 0
Rating (R)	3	$X^2_R =$ 25.7**
ExR	3	$X^2_{ExR} =$ 3.63
Total	7	$X^2_{Total} =$ 29.33**

** $p < 0.001$

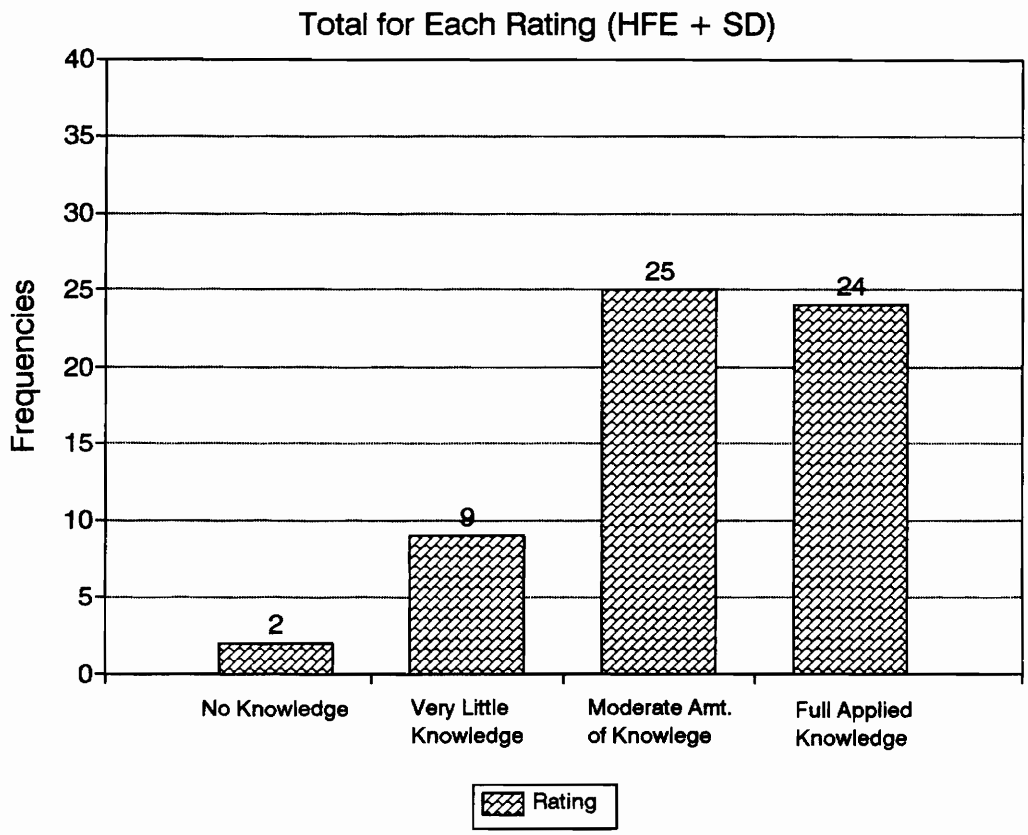

Figure 10. Frequency histogram of software industry term - end user.

Table 67. Sutcliffe Chi-Square Summary Table - Customer

Source	*df*	X^2
Education (E)	1	$X^2_E =$ 0
Rating (R)	3	$X^2_R =$ 33.73**
ExR	3	$X^2_{ExR} =$ 5.74
Total	7	$X^2_{Total} =$ 39.74**

** $p < 0.001$

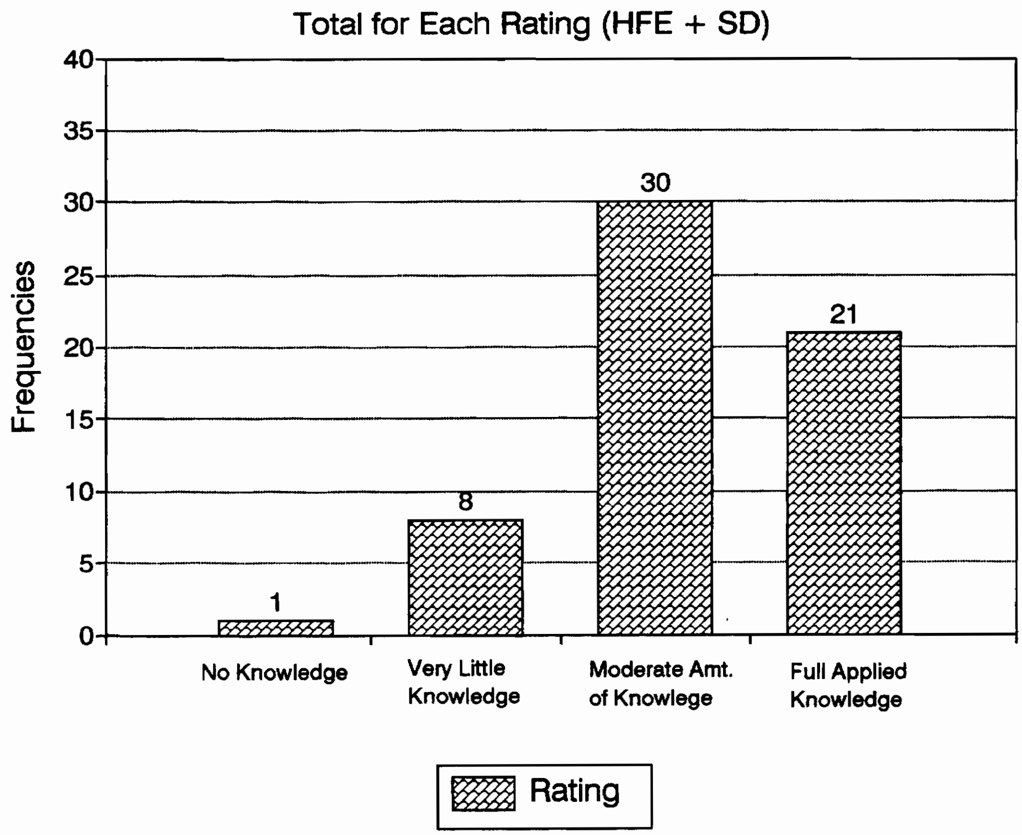

Figure 11. Frequency histogram of software industry term - customer.

Table 68. Sutcliffe Chi-Square Summary Table - Training Developer

Source	*df*	X^2
Education (E)	1	$X^2_E = 0$
Rating (R)	3	$X^2_R = 47.60^{**}$
ExR	3	$X^2_{ExR} = 4.93$
Total	7	$X^2_{Total} = 52.53^{**}$

** $p < 0.001$

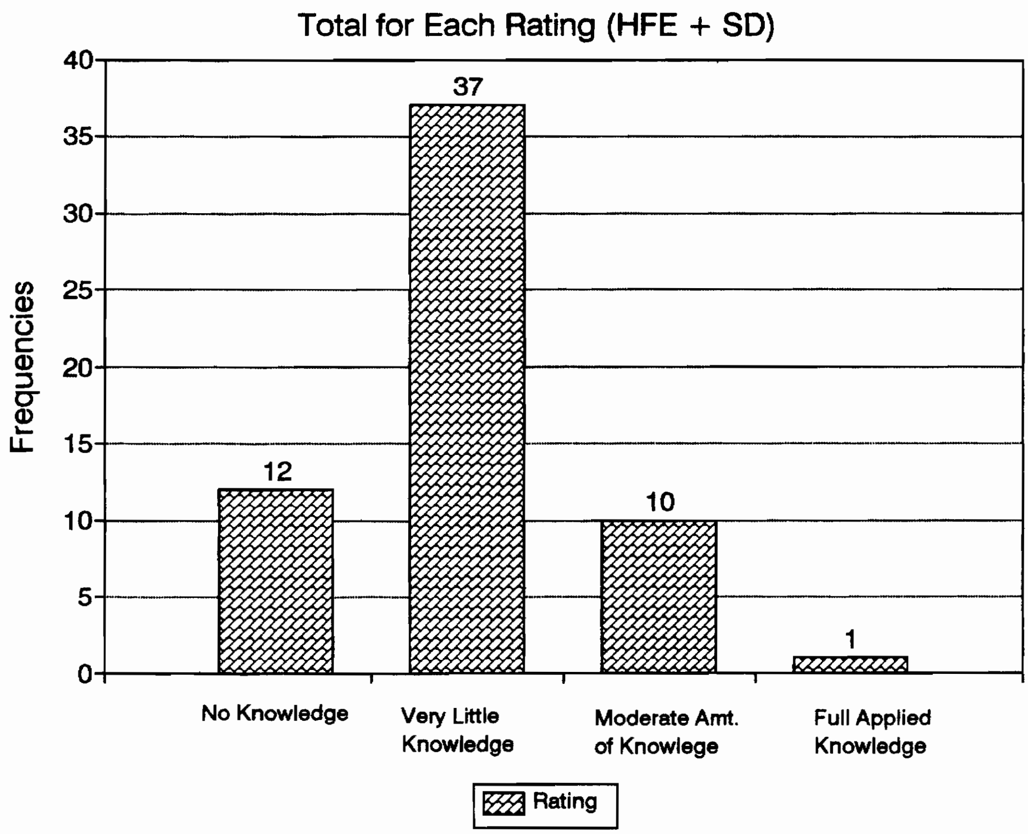

Figure 12. Frequency histogram of software industry term - training developer.

Table 69. Sutcliffe Chi-Square Summary Table - Marketing Specialist

Source	*df*	X^2
Education (E)	1	$X^2_E =$ 0
Rating (R)	3	$X^2_R =$ 30.27**
ExR	3	$X^2_{ExR} =$ 8.13*
Total	7	$X^2_{Total} =$ 38.40**

* $0.02 < p < 0.05$

** $p < 0.001$

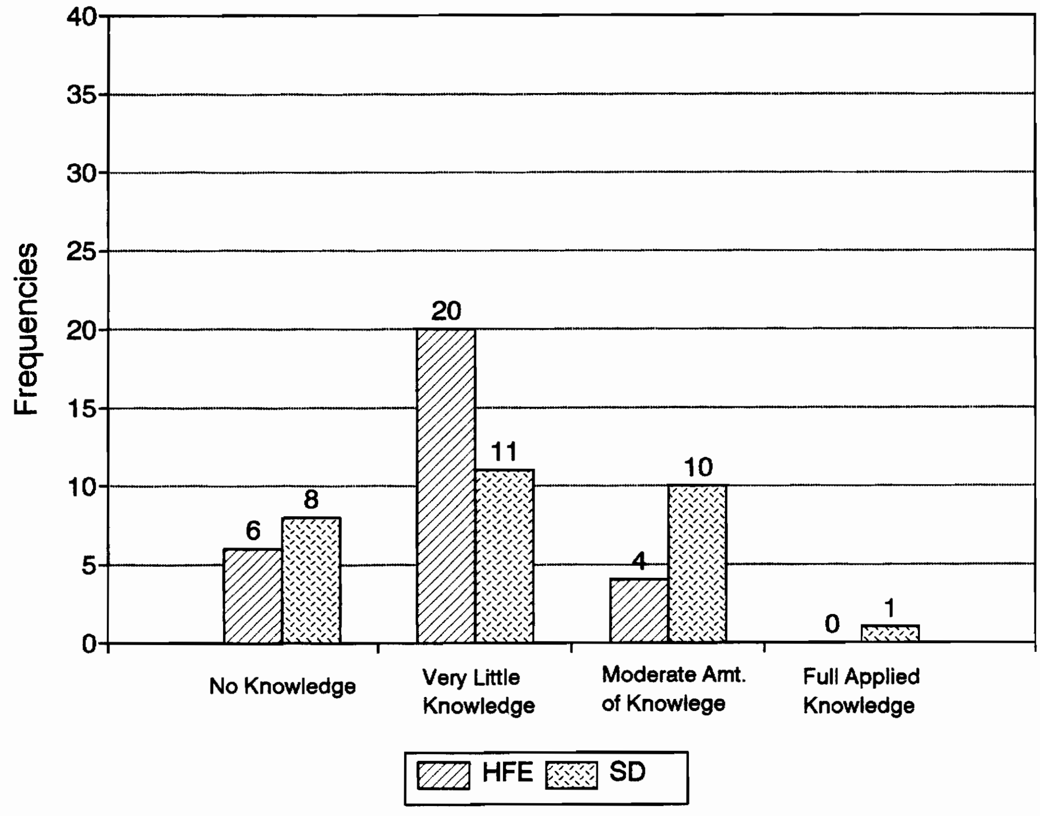

Figure 13. Frequency histogram of software industry term - marketing specialist.

Table 70. Sutcliffe Chi-Square Summary Table - Knowledge Worker

Source	*df*	X^2
Education (E)	1	$X^2_E =$ 0
Rating (R)	3	$X^2_R =$ 45.73**
ExR	3	$X^2_{ExR} =$ 4.67
Total	7	$X^2_{Total} =$ 50.40**

** $p < 0.001$

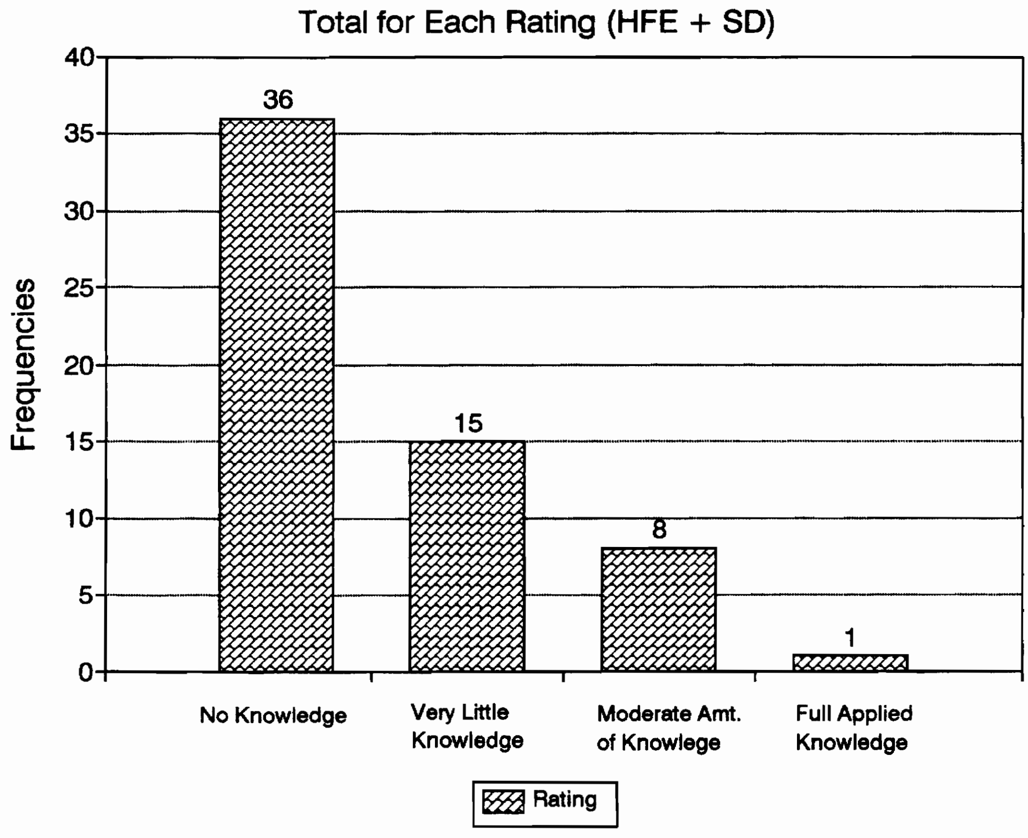

Figure 14. Frequency histogram of software industry term - knowledge worker.

Table 71. Sutcliffe Chi-Square Summary Table - Market Environment

Source	*df*	X^2
Education (E)	1	$X^2_E =$ 0
Rating (R)	3	$X^2_R =$ 35.33**
ExR	3	$X^2_{ExR} =$ 0.67
Total	7	$X^2_{Total} =$ 36.00**

** $p < 0.001$

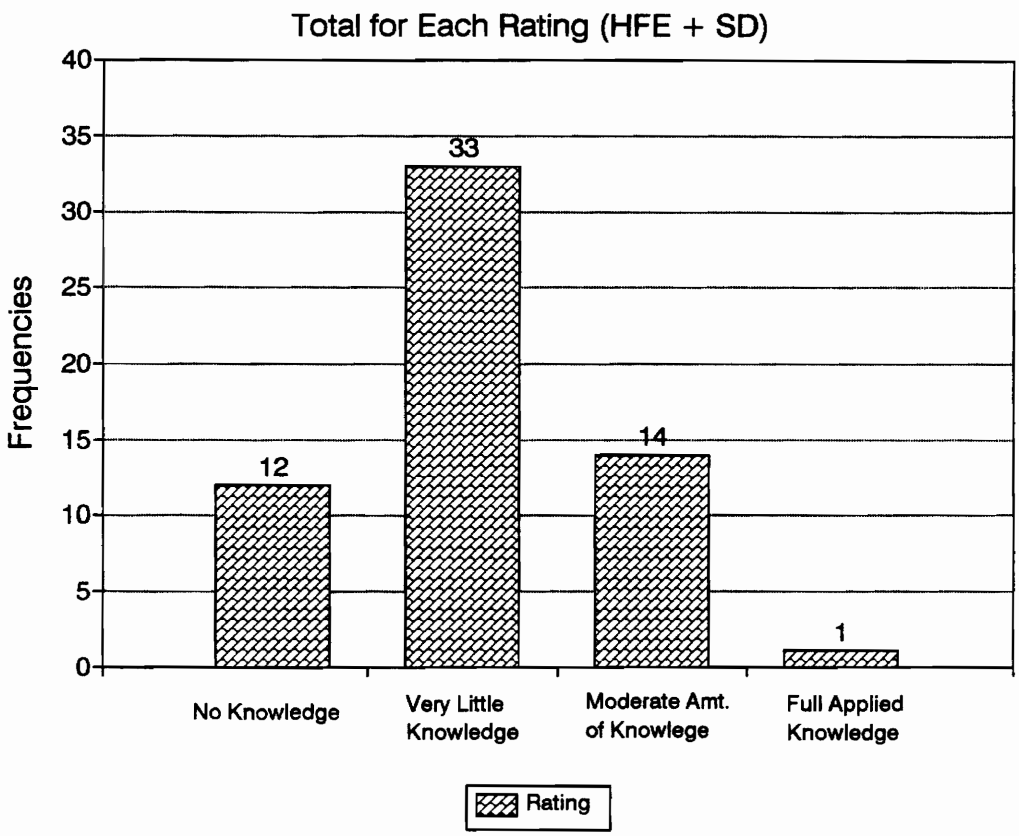

Figure 15. Frequency histogram of software industry term - market environment.

Table 72. Sutcliffe Chi-Square Summary Table - Prototype

Source	*df*	X^2
Education (E)	1	$X^2_E = 0$
Rating (R)	3	$X^2_R = 27.6^{**}$
ExR	3	$X^2_{ExR} = 0.13$
Total	7	$X^2_{Total} = 27.73^{**}$

** $p < 0.001$

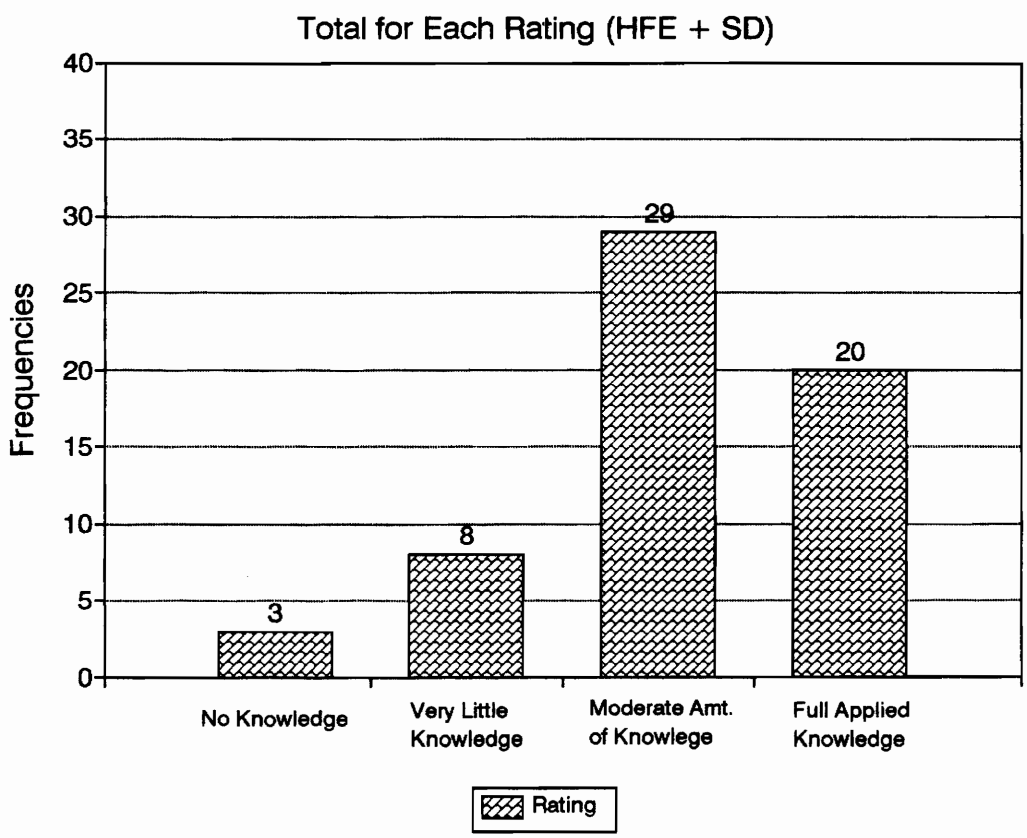

Figure 16. Frequency histogram of software industry term - prototype.

Table 73. Sutcliffe Chi-Square Summary Table - Software Product

Source	*df*	X^2
Education (E)	1	$X^2_E =$ 0
Rating (R)	3	$X^2_R =$ 31.20**
ExR	3	$X^2_{ExR} =$ 3.73
Total	7	$X^2_{Total} =$ 34.93**

** $p < 0.001$

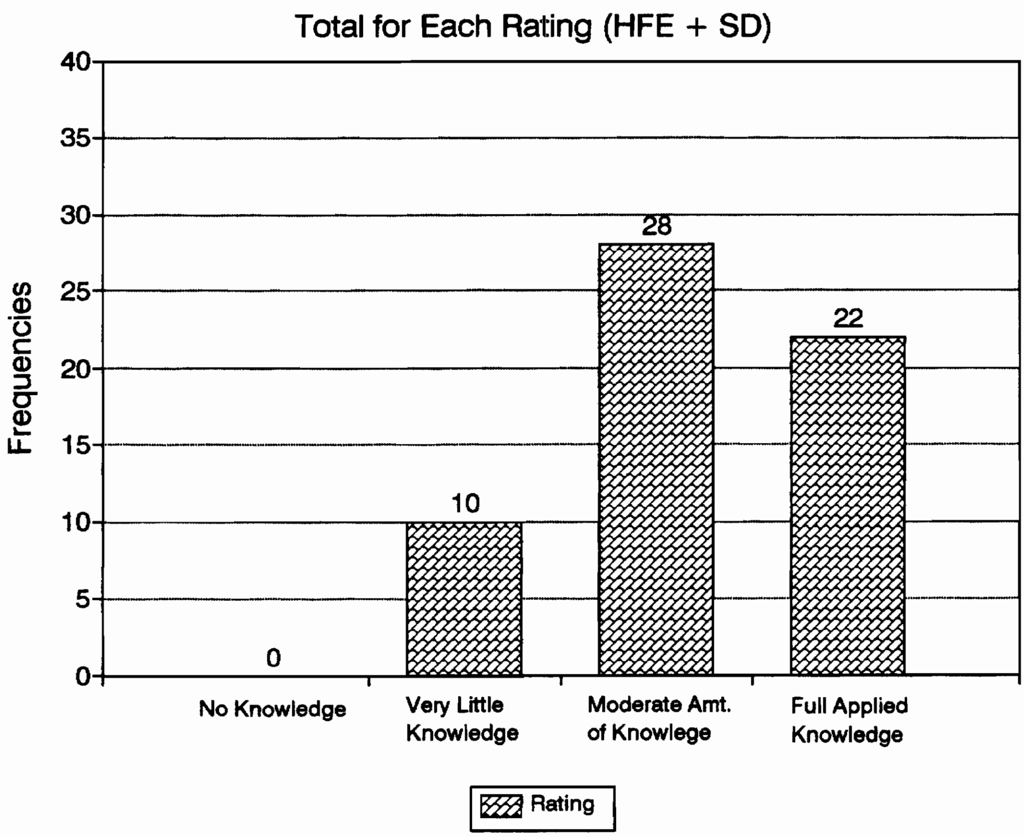

Figure 17. Frequency histogram of software industry term - software product.

Table 74. Sutcliffe Chi-Square Summary Table - Iteration

Source	*df*	X^2
Education (E)	1	$X^2_E =$ 0
Rating (R)	3	$X^2_R =$ 24.67**
ExR	3	$X^2_{ExR} =$ 4.93
Total	7	$X^2_{Total} =$ 29.60**

** $p < 0.001$

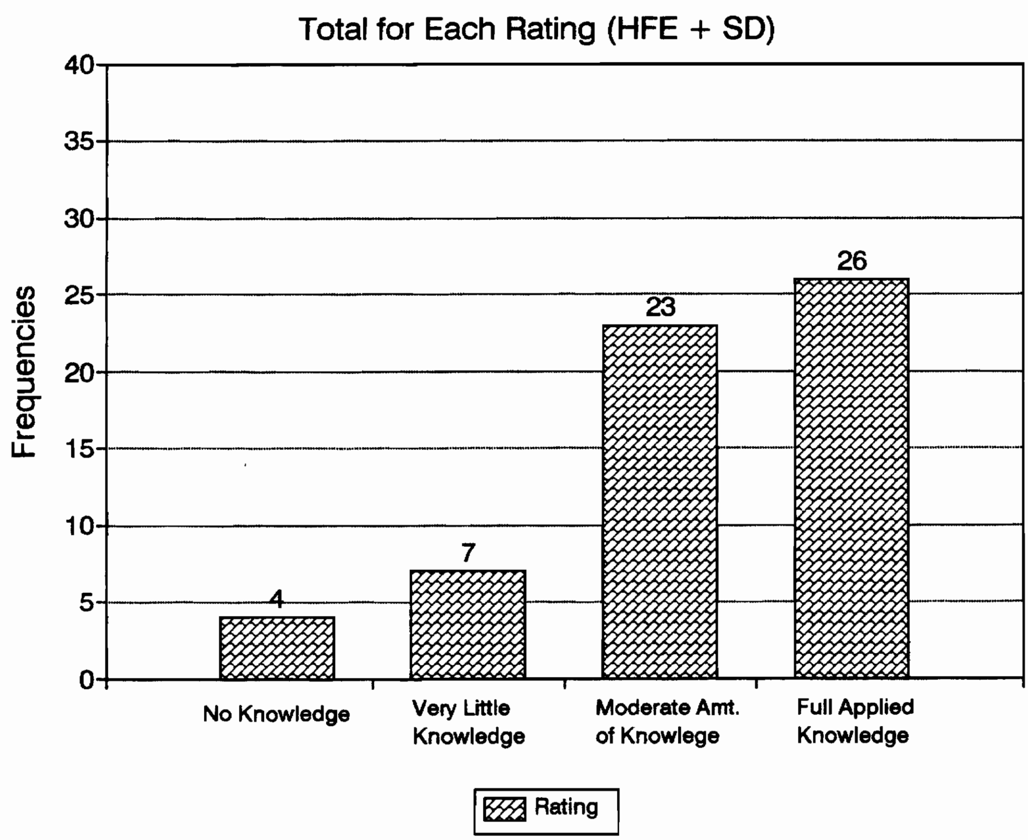

Figure 18. Frequency histogram of software industry term - iteration.

Table 75. Sutcliffe Chi-Square Summary Table - Task

Source	*df*	X^2
Education (E)	1	$X^2_E =$ 0
Rating (R)	3	$X^2_R =$ 23.23**
ExR	3	$X^2_{ExR} =$ 0.4
Total	7	$X^2_{Total} =$ 23.73**

** $p < 0.001$

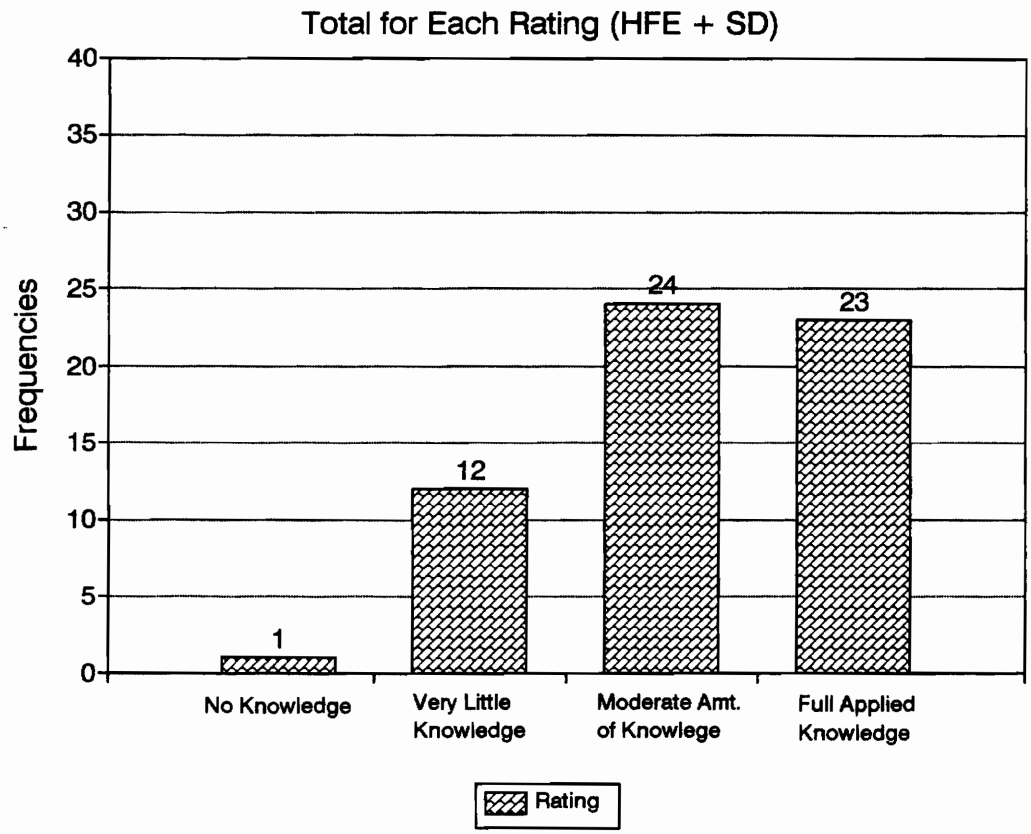

Figure 19. Frequency histogram of software industry term - task.

Table 76. Sutcliffe Chi-Square Summary Table - Usability

Source	*df*	X^2
Education (E)	1	$X^2_E = 0$
Rating (R)	3	$X^2_R = 34.40^{**}$
ExR	3	$X^2_{ExR} = 2.67$
Total	7	$X^2_{Total} = 37.07^{**}$

** $p < 0.001$

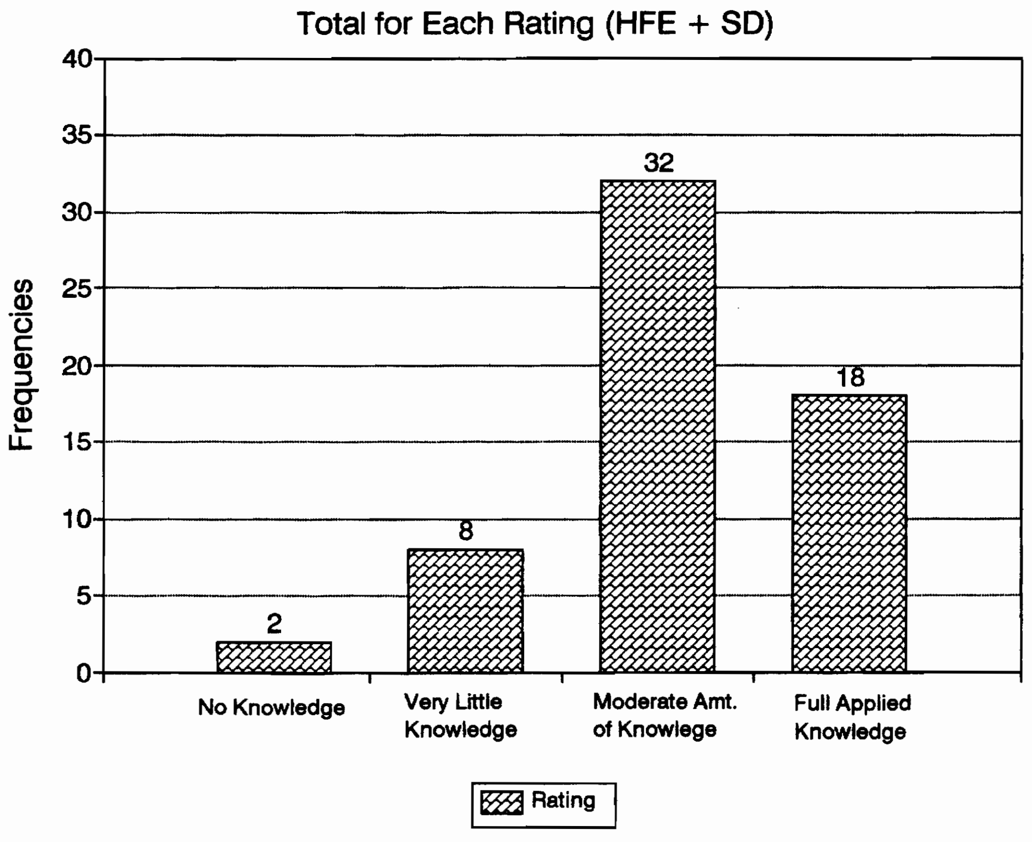

Figure 20. Frequency histogram of software industry term - usability.

Table 77. Sutcliffe Chi-Square Summary Table - Software Lifecycle

Source	*df*	X^2
Education (E)	1	$X^2_E = 0$
Rating (R)	3	$X^2_R = 14.80^{**}$
ExR	3	$X^2_{ExR} = 9.47^{*}$
Total	7	$X^2_{Total} = 24.27^{**}$

* $0.02 < p < 0.05$

** $p < 0.001$

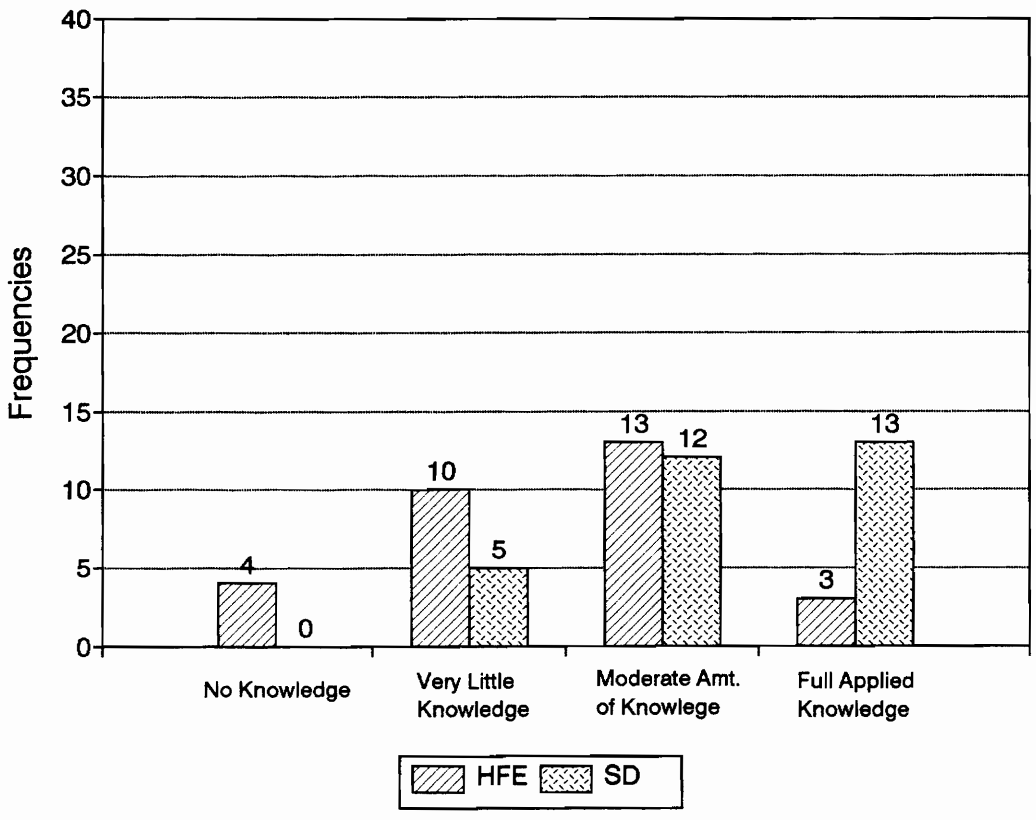

Figure 21. Frequency histogram of software industry term - software lifecycle.

Table 78. Sutcliffe Chi-Square Summary Table - Systems Design

Source	*df*	X^2
Education (E)	1	$X^2_E = 0$
Rating (R)	3	$X^2_R = 32.13^{**}$
ExR	3	$X^2_{ExR} = 3.34$
Total	7	$X^2_{Total} = 35.47^{**}$

** $p < 0.001$

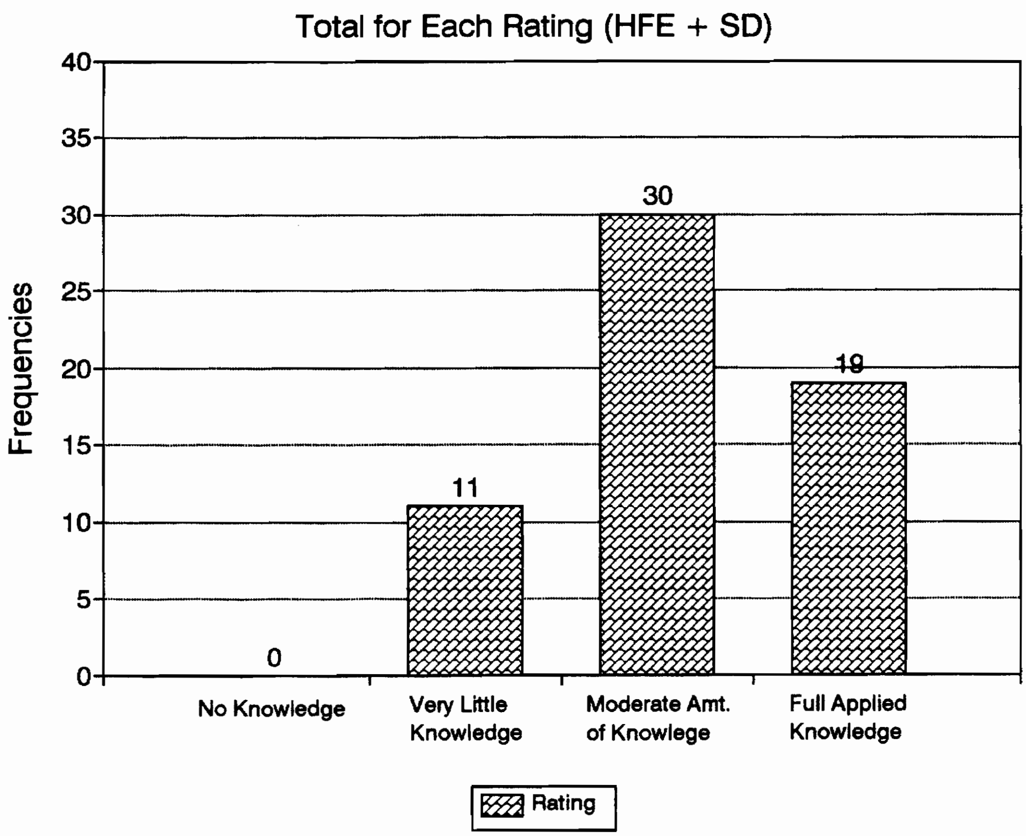

Figure 22. Frequency histogram of software industry term - systems design.

Table 79. Sutcliffe Chi-Square Summary Table - Software Engineering

Source	*df*	X^2
Education (E)	1	$X^2_E =$ 0
Rating (R)	3	$X^2_R =$ 21.73**
ExR	3	$X^2_{ExR} =$ 2.00
Total	7	$X^2_{Total} =$ 23.73*

* $0.02 < p < 0.05$

** $p < 0.001$

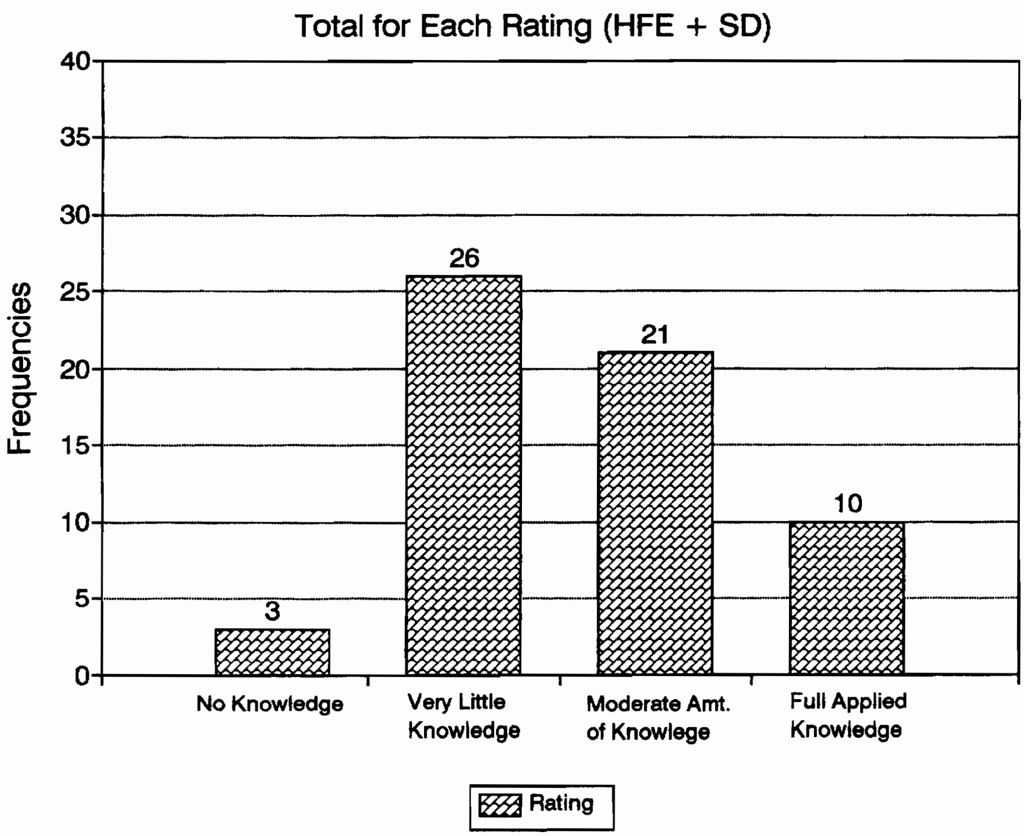

Figure 23. Frequency histogram of software industry term - software engineering.

Table 80. Sutcliffe Chi-Square Summary Table - Usability Engineering

Source	*df*	X^2
Education (E)	1	$X^2_E = 0$
Rating (R)	3	$X^2_R = 15.33^{**}$
ExR	3	$X^2_{ExR} = 8.94^{*}$
Total	7	$X^2_{Total} = 24.27^{**}$

* $0.02 < p < 0.05$

** $p < 0.001$

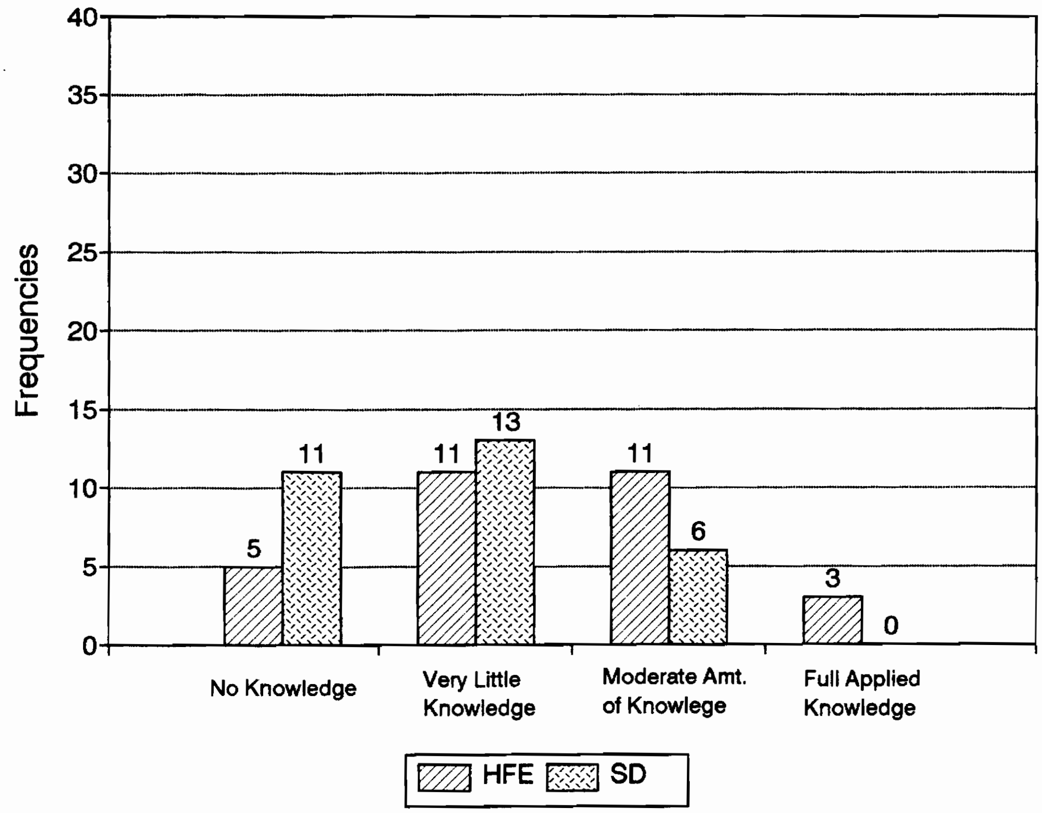

Figure 24. Frequency histogram of software industry term - usability engineering.

VITA

ROXANNE F. BRADLEY received a B.A. degree in mathematics from Texas Christian University. After receiving her degree, she taught sixth and eighth grade mathematics (1977-1980). In 1980, Ms. Bradley moved to San Francisco and began working in the computer industry. She has held several positions, many of which involved designing user interfaces. She is currently a graduate student in human factors engineering in the Department of Industrial and Systems Engineering at Virginia Polytechnic Institute and State University. Her research interests include the development of tools and techniques to aid developers in designing easy-to-use interfaces.

Roxanne Bradley