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ABSTRACT

This paper details a study of knowledge-building activities in the domain of computer software. Thirty-six adults--evenly split among beginning, intermediate, and advanced knowledge levels--were videotaped while they attempted to learn a common spreadsheet package. Subjects were asked to think aloud while learning. Each knowledge building activity was given a score based on how much was learned and how much time was gained or lost. Tabulations revealed that directed search, trial and error, and careful observation had the strongest impact on learning; pace of learning and systematic testing had a more moderate effect. From these results, a list is drawn of suggestions for educators who are trying to learn software, including making searches for help more focused instead of wasting time with frantic random keystrokes. Three tables summarize the data. (Contains 18 references.) (BEW)

Identifying Effective Knowledge Building Activities for Learning Computer Software

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paper

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Abstract

This study looked at knowledge building activities (KBAs) in the domain of computer software. Thirty-six adults were asked to think aloud while learning a series of tasks in a common spreadsheet package. A detailed analysis of 3,061 KBAs revealed that directed search, trial and error, and careful observation had a strong impact on learning. Pace of learning and systematic testing played a more moderate role. Practical recommendations are offered to educators of computer studies.

Introduction

The exploration of knowledge building activities (KBAs) originates from task-analysis in human factors engineering (Drury, Paramore, Van Cott, Grey, & Corlett, 1987) and involves breaking down tasks into smaller components and specifying the flow of those components (Brooks, 1991). A partial list of KBAs that have been identified in a variety of domains includes defining terms (Bransford, Vye, Adams, & Perfetto, 1989), planning (Miyata & Norman, 1986, Riley, 1986; Voss, 1989), searching (Schauble & Glaser, 1990), questioning (O'Malley, 1986), and a mixture of successful strategies (rehearsal and review, monitoring, unpacking implicit assumptions, summarizing, considering alternatives, questioning, clarifying and predicting) (Bereiter & Scardamalia, 1989; Brown & Palinscar, 1989; Collins, Brown, & Newman, 1989).

A number of investigators in the area of education and cognitive science have argued for more research on the knowledge building process. Chi & Bassok (1989) maintain that there is a need for more explicit examples describing the conditions surrounding KBAs. Glaser (1990) and Glaser & Bassok (1989) note that while considerable advances have been made in the areas of memory organization, problem solving, and characteristics of understanding, the knowledge acquisition process has not been examined extensively. Furthermore, few researchers have offered a detailed analysis of knowledge building characteristics in a natural setting (Ceci, 1990; Siegler, 1989).

Research on KBAs has been noticeably absent in the computer ability literature. For the most part, studies have relied solely on a paper-and-pencil format to gather information about knowledge of using computers. This relatively straightforward strategy has produced a wealth of well-organized, albeit conflicting, information (Kay, 1989, in press) offering little understanding of the dynamics of human-computer interaction.

The primary purpose of this study was to examine knowledge building activities used to learn new computer software. The specific objectives were to (a) describe the principle KBAs in the computer knowledge acquisition process, (b) examine the extent to which these activities were associated with successful problem solving; (c) demonstrate how the results can be used to advance knowledge and theory; and (d) provide meaningful suggestions for educators of computer studies.

Research Design

Sample

The sample consisted of 36 adult volunteers (18 male, 18 female): 12 beginners, 12 intermediates, and 12 advanced users, ranging in age from 23 to 49 (M= 33.0 years), living in the greater metropolitan Toronto area. The criteria used to determined ability levels included years experience, previous collaboration, learning, software experience, number of application software packages used, number of programming languages/operating systems known, and application software and programming languages known. A MANOVA showed that beginners, intermediates, and advanced users had significantly different scores in the expected direction on all seven criteria ($p < .005$).

Procedure

Subjects' computer activities were videotaped for 55 minutes, with the camera focused on the screen, while they attempted to learn a common spreadsheet package (Lotus 1-2-3, Version 2.2) on an IBM 80286 clone. Subjects were asked to do as many of the following tasks as they could: (1) move the cursor, (2) enter rows and columns of numbers, (3) enter data, (4) insert blank rows and columns, and (5) move and/or copy rows or columns of data. The standard procedure was to introduce the subject to a task and encourage self-directed learning. Each subject was asked to think out loud while learning. Every effort was made to encourage subjects to get "unstuck" on their own. Unlike typical protocol analysis, subjects were given calculated "hints" when they were unable to proceed.

Data Collection

The first 50 minutes of each of the 36 videotaped sessions was transcribed verbatim. Verbal expressions and sounds, as well as critical keystrokes, were included in the transcriptions. Transcription analysis revealed that 3,061 learning episodes involved some sort of knowledge building activity.

Each KBA was assigned an influence rating based on (a) how much was learned and (b) time lost or gained. If no knowledge or understanding was lost or gained, a score of 0 was given. If a small piece of the task was solved or misconstrued a score of +1 or -1 was assessed respectively. If a significant piece of the task was learned or misconstrued, a score of +2 or -2 was assessed. Finally if a substantial amount of time (15-20 minutes) was gained or lost, in the process of learning or misconstruing, a score of +3 or -3 was given. A detailed coding scheme was used to ensure the reliability of influence ratings.

Next, an estimation of effect for a specific category of KBA was calculated using the average influence rating for that category, the percentage of subjects involved, and the total number of observations made. For example, if the KBA category "seeking information" showed an average influence rating of 1.2, was used by 50% of the subjects (n=18), and accounted for a total of 45 observations, the estimated effect score would be 27 (1.2 x .50 x 45).

Main Variables

The main independent variables were based on five principle KBAs identified in the protocol data: (a) actions (e.g. pressing a key, playing, exploring), (b) seeking information, (c) processing information, (d) style (e.g. going at a fast or slow pace), and (e) combinations of learning activities. Within these categories, a number of sub-categories were identified and are presented in Table 1. The main response variable was the estimated effect score.

Results

Description of Principle KBAs

Seeking information (48%) and specific actions (36%) were the two most prolific KBA categories. Main activities based on style (9%), processing of knowledge (5%), and combinations of activities (1%) were seen much less often . Trial and error, searching (specific and broad), and observing were the top sub-categories of learning observed. Subjects' pressed any key, repeated their actions, performed systematic tests, asked for help, used deduction and changed their pace of learning with a moderate degree of frequency.

Table 1: Type and Frequency of Knowledge Building Activities

CATEGORY	# of Obs.	% of Category	CATEGORY	# of Obs.	% of Category
ACTIONS			KNOWLEDGE PROCESSING		
Trial & Error	608	54%	*Deduce*	106	64%
Press Any Key	127	11%	*Reflect*	42	25%
Repeat Action	114	10%	*Compare*	18	11%
Sys. Test	114	10%	*TOTAL*	166	5%**
Exploring	63	6%			
Anchoring	62	5%	STYLE		
Playing	25	2%	*Fast-Pace*	118	41%
Circling	15	1%	*Slow-Pace*	101	35%
TOTAL	1128	36%**	*Double-Check*	61	21%
			Evaluate	11	4%
SEEK INFORMATION			*TOTAL*	291	9%**
Search Specific	566	38%			
Search Broad	454	31%	Combining KBAs	32	1%**
Observe	351	24%			
Ask for Help	108	7%			
TOTAL	1479	48%**			

Note: ** Percent of all KBAs

Estimated Effect of KBAs on Learning

The highest effect score came from attempts to seek information (990.9) and actions subjects made (699.4). Searching for specific information produced the single highest effect score (600.0) for a specific learning activity, followed by trial and error (486.4) and observing (358.0). More modest effect sizes were seen in broad searches for information (140.7), a slow and fast pace of learning (100.3 and -115.1 respectively), and systematic testing (99.6). Notable negative effects were produced by pressing any key (-55.8) and going at fast pace (-115.1)

It is interesting to note the highest mean influence scores were not necessarily produced by those activities with the highest effect scores. In fact, combining KBAs showed the highest mean influence (M=1.56) followed by change of pace (M=1.27 & 1.25), double-checking actions (M= 1.21), and systematic testing (M=1.21). Two of the highest estimated effect activities, specific searches and observing had relatively high mean influences (M=1.06 and 1.02 respectively). Other relatively high influence activities included comparing (M=1.00) and asking for help (M=1.06). A complete set of estimated effects for main and sub-categories of learning activities is presented in Table 2.

Table 2: Estimated Effect as a Function of KBAs

CATEGORY	n	% of Subjects	Mean Influence	Estimated Effect
ACTIONS				
Trial & Error	608	100%	0.80	486.4
Systematic Testing	114	78%	1.12	99.6
Repeat Action	114	92%	0.53	55.6
Exploring	63	86%	0.79	42.8
Anchoring	62	69%	0.74	31.7
Playing	25	33%	0.36	3.0
Circling	15	28%	-0.47	-2.0
Press Any Key	127	72%	-0.61	-55.8
TOTAL	1128	100%	0.62	699.4
SEEK INFORMATION				
Search for Specific Info.	566	100%	1.06	600.0
Observing	351	100%	1.02	358.0
Search Broad	454	100%	0.31	140.7
Ask for Help	108	78%	1.06	89.3
TOTAL	1479	100%	0.67	990.9
KNOWLEDGE PROCESSING				
Deduce	106	92%	0.72	70.2
Reflect	42	69%	0.81	23.5
Compare	18	36%	1.00	6.5
TOTAL	166	100%	0.77	127.8
STYLE				
Slow-Pace	101	86%	1.27	110.3
Double-Check	61	78%	1.21	57.6
Evaluate	11	17%	0	0.0
Fast-Pace	118	78%	-1.25	-115.1
TOTAL	291	97%	0.19	53.8
COMBINING KBAs	32	33%	1.56	16.5
ALL KBAs	3061	100%	0.60	1836.6

Finally, an analysis of KBAs as a function of ability showed advanced users to be more capable with respect to trial and error, observation, searching for information, and double checking their answers. Paradoxically, they experienced more difficulty than beginners or intermediates when they attempted to go too fast. Estimated effects for all learning activities as a function of ability are present in Table 3.

Table 3: Estimated Effect as a Function of Learning Activity and Ability Level

Learning Activities (*from Resources*)	Beginner Est. Effect	Intermediate Est. Effect	Advanced Est. Effect
ACTIONS			
Anchoring	7.4	14.2	10.7
Circling	-1.0	-0.5	-0.5
Exploring	18.3	15.6	9.7
Press any key	-23.9	-17.3	-14.2
Repeat an action	15.6	14.2	25.9
Systematic test	30.7	45.0	24.7
Trial & Error	146.3	143.5	197.8
SEEKING INFORMATION			
Ask for help	29.3	26.5	32.5
Observe	110.7	108.9	138.8
Search Specific	71.8	128.5	194.9
Search Broad	20.6	34.3	42.3
KNOWLEDGE PROCESSING			
Comparing	0.3	3.0	4.2
Deducing	24.9	30.0	15.8
Reflecting	8.6	5.5	9.2
STYLE-RELATED			
Double-check	10.0	16.4	33.8
Evaluate software	-0.1	0.0	0.5
Fast-Pace	-16.2	-44.9	-54.0
Slow-pace	33.7	37.5	38.0
COMBINATION	0.5	1.5	21.0

Theoretical Implications

Identification of KBAs for computer knowledge acquisition has proven to be a useful procedure yielding a mixture of traditional and unique behaviors. KBAs observed in this study that were noted previously in other domains included searching (Schauble & Glaser, 1990), monitoring or observing, and review (double checking) (Bereiter & Scardamalia, 1989; Brown & Palinscar, 1989; Collins, Brown, & Newman, 1989). Traditional KBAs, such as rehearsal, unpacking of implicit assumptions, summarizing, considering alternatives, clarifying, and predicting (Bereiter & Scardamalia, 1989; Brown & Palinscar, 1989; Collins, Brown, & Newman, 1989) were not seen frequently in this investigation. Some knowledge processing activities and strategies, though, such as deduction, reflecting, and comparing were observed occasionally, with modest effects on learning.

Influential KBAs, seemingly indigenous to the computer environment, included *trial and error* and *systematic testing*. Less powerful KBAs, also unique to software use were *anchoring* (always coming back to the same spot) and random, rapid *pressing of any key*. In addition, pace of KBAs, categorized under style, appeared to be important in learning. *Fast key pressing, quick searching* or *hasty observations* lead to mistakes and a negative effects on learning. Slowing down on the other hand increased learning effectiveness.

The nature of the domain in this study may have partially determined the nature of KBAs expressed. Computer software is set up to naturally try keys, and offer instant feedback, usually with minimal repercussions. A trial and error strategy can be useful for providing new information and constraints to guide future actions and learning. While the mean influence of trial and error activity is only moderately high, instant feedback makes it a useful strategy, when employed frequently and with a certain amount of prudence. Aimless key pressing or rushing on to the next key has a definite negative effect on learning, primarily because the subject can neither see nor cognitively digest what has happened. Systematic testing and taking the necessary time to observe and interpret feedback, is an optimal approach. Exhaustive searches of the manual or on-line help, or careful planning and deduction, may not appear worthwhile given the relative efficiency of trying specific keys in a constrained and systematic manner. The potential for considerable time loss and absence of immediate feedback, makes the trial and error strategy somewhat inefficient for non-computer software domains.

The quality of searching seems to be fundamental to success in learning with computers. Specific searches were more than four times more effective (600 to 141) and three times more efficient (1.06 to 0.31) than broad searches. Specific searching is characterized by searching for meaning or specific phrases, whereas broad searching involved general scanning and page turning. It is reasonable to assume that a more specific search strategy is linked to ability level and more specifically to one's understanding of terminology and concepts. Advanced users have a better idea of what to look for, whereas a beginners, are sometimes forced to search broadly, because they do not know where to focus their efforts.

The key KBAs noted above were instrumental in distinguishing advanced user from their less able counterparts: trial and error, observation, searching for information, and double checking their answers. Somewhat unexpectedly, advance users have an Achilles heel–they attempt to go too quickly and their learning suffers as a result.

One final observation: although the number of times subjects' combined strategies was minimal (n=32), the mean influence of this KBA was the highest observed. Ultimate success with learning new computer software may rest on combining the strategy of slowing down, with careful observation, searching as specifically as possible, and trying keys in a systematic manner.

Suggestions for Educators

The findings in this section suggest several clear guidelines for educators of computer studies. These include:

- A trial and error strategy appears to work well.
- The effectiveness of trial and error is increased by using a more systematic approach. Pressing any key randomly is unlikely to help learning and will moderately impede progress.
- Taking time to observe not only key strokes, but what is on the screen and in the book appears to be highly related to success.
- When searching a manual, on-line help, or a menu, specific searches are four times more effective and a three times more efficient than broad searches (e.g. turning pages, scanning). Activities supporting the labeling of new actions and concepts might support a more specific search technique.
- Deduction, reflection, and comparing do not appear to play a important role in short term learning of new software.
- A combination of the above strategies may be the most effective way to improve learning with computers. In other words, each additional piece may increase a student's overall chances of success.

Caveats

Several cautions should be noted with respect to the results of this study. First, the rating system focused on short-term learning–the conclusions do not necessarily apply to long term gains. Second, only one software package was assessed–different software areas might require different KBAs. Finally, while over 3000 observations were made, the sample size (n=36) was relatively small and localized.

Summary

Knowledge building activities play a prominent role in computers and learning. While certain KBAs observed, such as searching, monitoring, and review were observed previously in other domains, KBAs such as trial and error and systematic testing appeared to be unique to the computer environment. KBAs noted in other subject areas, such as rehearsal, planning, unpacking assumptions, and summarizing played a negligible role in this study. It was suggested that the nature of the computer software domain may have effected the frequency and quality of KBAs observed. An examination of all learning activities indicated that a slow, deliberate, trial and error strategy, coupled with observation, and more focused searching techniques would be an optimal approach to learning new software.

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