Users' Knowledge Aquisition and Utilization in User-Product Interaction

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"This work was supported by the Korea Research Foundation Grant funded by the Korean Government" (KRF-2008-411-J05001)

Abstract

When using an interactive product or system to achieve a goal, a user utilizes his/her existing knowledge and acquires new knowledge. Throughout this process, the user's knowledge is constantly modified and generated. In the current technological era, however, interactive products and systems do not provide enough opportunities for users to generate their own knowledge in interaction. Rather, knowledge needed for producing quality results tend to be hidden behind product operation, not communicated to users. As a result, users' experience in interaction tends to be confined to passive machine-operating procedures, and users may not be able to learn how to adjust their product use in order to achieve quality results in various situations.

When designers seek to fully support users' goal achievement in interaction, they should consider how to support users' effective and efficient knowledge development. To this end, this particular paper aims to investigate users' knowledge acquisition and utilization process in their interaction with a product. This paper first defines what kinds of knowledge are involved in user-product interaction and what components and factors shape users' learning experience. Then, the effects of users' levels and types of knowledge on their knowledge process are investigated through some observational user studies. The observation results particularly emphasize that in order to achieve quality results through interaction, it is necessary for users to acquire and properly apply sufficient problem-solving knowledge of the domain of concern (i.e. domain knowledge).

Keyword
Interactive product design, Operation and domain knowledge, Users′ learning experience

1. Introduction

When using a digital product or system to achieve a goal, a person utilizes his/her existing knowledge and acquires new knowledge. Throughout this process, the user's knowledge is constantly modified and generated. By viewing users' interaction with products as their knowledge-building (i.e. learning) process, designers can try to improve the quality of user-product interaction from the perspective of how to enhance users' learning experience. In the current technological era, however, interactive products and systems do not provide enough opportunities for users to generate their own knowledge in interaction. Rather, knowledge needed for producing quality results tend to be hidden behind product operation, not communicated to users. As a result, users' experience in interaction tends to be confined to passive machine-operating procedures, and users may not be able to learn how to adjust their product use in order to achieve quality results in various situations.

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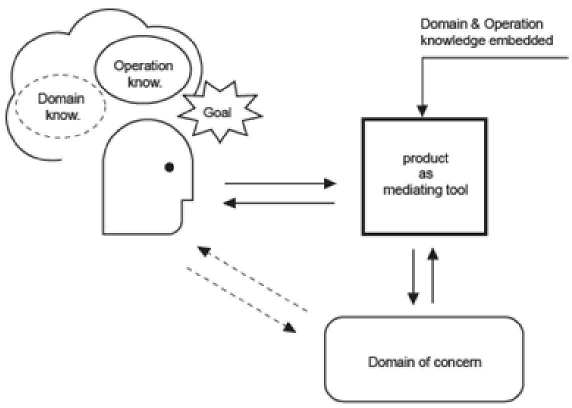
2. Knowledge Development through Interaction

2.1. Knowledge Involved in Product Use

When using a product or system to achieve a goal, people utilize their existing knowledge and acquire new knowledge. Knowledge involved in the use of an interactive product has been understood as knowledge processed within the user's mind since the 1960s and 1970s, based on insights from cognitive psychology. This approach regards a user as an information processor (Card, Moran, & Newell, 1983). However, recent approaches to understanding users have more focused on a human ability in autonomously controlling their interaction behaviors. In other words, users are conceived to actively interact with knowledge embedded in products, rather than to passively process inputted information (Kuutti, 2001).

Considering users' interaction as their knowledge formation process, it is necessary to identify what kinds of knowledge are involved in this process. According to Choi, Choi, and Sato (2008), knowledge involved in interaction can be classified into two types: knowledge of how to operating a product/system (operation knowledge) and knowledge of problem-solving mechanisms in the domain of concern (domain knowledge). For example, when people bake bread using a bread machine, they may need knowledge of how to operate the bread machine (operation knowledge) and knowledge about how to bake desired-quality bread (domain knowledge). Figure 1 describes operation and domain knowledge involved in the relationships between a user, a product, and a domain.



[Figure 1] Types of knowledge in user-product interaction (modified from Choi et al., 2008)

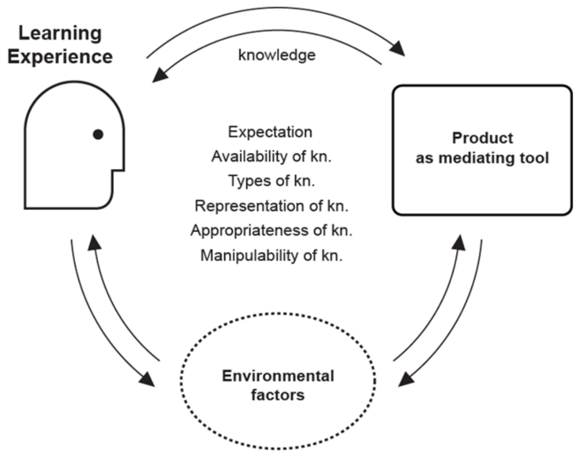
This classification is based on the activity theoretical point of view, which considers artificial products and systems as "carriers of cultural knowledge and social experience" (Kaptelinin, 2001, p. 109). In other words, products and systems can be considered to be tools which mediate knowledge between the user and the domain of concern. Knowledge embedded in a product is presented to a user by means of the functions and attributes of a specific product.

In the current advanced technological era, while users' acquisition of operational knowledge is increasingly emphasized, users' domain knowledge has largely been disregarded. As Kuutti (2001) points out, there will always be certain capabilities and limitations of a particular tool's feature, which either enables or limits a user's goal achievement. When users greatly rely only on the machine operation procedures, without having knowledge of the domain (e.g. principles of baking), they may not be able to deal with the machine's malfunctioning and how to flexibly utilize the machine to meet their variable needs.

2.2. Components and Factors of Users' Learning Experience

This research tries to conceptualize users' knowledge development process (i.e. learning experience) through the interaction with a product or system, as depicted in Figure 2. The proposed model describes not only users' internal cognitive processes but also the influences of the product/system features and environmental factors on users' knowledge process. The model identifies three structural components: user, product, and environmental factors. The interplay among these components in users' knowledge acquisition and utilization process can be affected by some factors that have been explored in theories of learning motivation (e.g. Keller, 1987), self-regulation (e.g. Zimmerman, 1994), and internal/external information representation (e.g. Zhang & Norman, 1994).

- User expectation (Ex): What kinds and levels of expectations users have for the user-product interaction
- Availability of knowledge (Av): Whether the particular knowledge necessary for users' interaction and goal achievement is available in their memory or external sources
- Types of knowledge (Tp): What types of knowledge users have: product operation knowledge and domain knowledge
- Appropriateness of knowledge (Ap): How appropriate the knowledge that users have or a product presents is for their goal achievement, in terms of reliability, relevance, etc.
- Representation of knowledge (Rp): Whether the external representation of knowledge embedded in a product or sources can fit users' internal representation
- Manipulability of knowledge (Mn): How effectively and efficiently a user can manipulate the knowledge involved in interaction.



[Figure 2] Components and factors of user's learning experience

These six factors in learning experience are closely interrelated. Users' learning experience can be understood as the result of combinational operations and dynamic interactions among these factors and components over time.

3. Research Methods

In order to investigate how users' levels and types of knowledge actually affect their performance and experiences in using a product, this research conducted two sets of observational user studies: a digital camera and a coffee maker study.

3.1. Data Collection Methods

3.1.1. Elicitation of users' learning process

How to elicit users' thinking processes has been an important issue among design researchers because the proper identification of internal processes is critical to understanding external performance. A typical way to reveal users' mental processes is to ask them to verbalize their thoughts while completing given tasks using a product, which is known as think-aloud. However, as some researchers pointed out (e.g. Sasse, 1997), think-aloud is a highly artificial way of obtaining verbal protocol data; users may not be able to provide proper verbal accounts of their thought. In order to let users verbalize their thinking process in a more natural way, this particular study paired two people and asked them to complete tasks together using a product, aiming to make users' verbalization of their knowledge process a natural part of their task performance. In order to prevent interaction processes from being dominated by one participant, the investigator assigned them to take turns in leading and in supporting a task execution.

3.1.2. Tasks and questionnaires

A series of tasks were devised for each of the digital camera and coffee maker study. For both studies, an observational session started with a non-structured task which asked participants to explain their ordinary process of using a digital camera or a coffee maker. Then, more structured tasks were provided, asking them to use a given product to achieve the tasks. Those tasks were devised to examine either/both operation and domain knowledge. In the coffee maker study, participants had one task: making four cups of coffee. In the camera study, four tasks were given: taking a picture of a painting after turning off the flash, taking a full picture of tiny earrings, checking how many more pictures the camera can take, and deleting pictures and reducing the image size. Participants were allowed to refer to any sources of knowledge necessary for completing a task, such as the user's manual or the Internet.

Before an observation session, a pre- observation questionnaire was given to participants in order to assess their previous experience with and existing knowledge of the product and domain. This information was later used to explicate user actions, rationale, and task performance. In addition, a post-observation questionnaire asked about the experience with the given product and elicited self-evaluation of task performance. It was especially important in the post-observation questionnaire to ask participants how they would improve the photos or coffee if they were not satisfied with them, in order to assess whether they had obtained proper knowledge and to infer their future performance. In order to estimate their learning curve, a few follow-up observations of each group were conducted in the same settings three weeks later.

3.1.3. Participants

For active conversations between participants, a pair of participants previously acquainted with each other was recruited together for each session. Since users' existing knowledge can significantly influence their learning process, knowledge levels of candidates for participation (novice / expert) in both domain knowledge and operation knowledge were examined in the recruiting process by asking them some screening questions. For example, in the camera study, participants were regarded as experts in the photo-taking domain when they were familiar with the principles of controlling exposure (such as adjusting the aperture and shutter speed). Also, participants who were familiar with setting camera options (such as selecting a shooting mode and an image size) were considered as experts in operating a camera. Consequently, for each camera and coffee maker study, four types of participant groups were organized: (1) product operation novices and domain novices (OpN/DmN), (2) product operation experts, but domain novices (OpE/DmN), (3) product operation experts and domain experts (OpE/DmE), and (4) product operation novices, but domain experts (OpN/DmE). Six participants to form three pairs were recruited for each group, thus, twenty-four people participated in each experiment (see Table 1).

[Table 1] Group organization according to types of knowledge and users' knowledge levels

Groups	Domain novice	Domain Expert
Operation novice	OpN/DmN: 3 pairs	OpN/DmE: 3 pairs
Operation expert	OpE/DmN: 3 pairs	OpE/DmE: 3 pairs

(Total number of participants:
24 for the camera / 24 for the coffee maker)

3.1.4. Product features

The digital camera chosen for this study has some automatic functions and some semi-manual functions. The features of this camera that can affect the quality of pictures include an exposure control, a shutter speed control, a white balance setting, a color tone setting, a choice of ISO speed, a flash setting, an image resolution setting, the lighting condition, etc. The coffee maker used in this study has a grinding function in addition to regular brewing features. The entire coffee-making cycle - from grinding to brewing - is set in a motion by pressing the start button. Using this machine, users can adjust the taste of coffee to their preference by controlling several variables: the amount of coffee beans, the amount of water, and the fineness of coffee ground.

3.2. Data Analysis Methods

This research analyzed data collected from two case studies using the Modular Script Scenario (MSS) method, as shown in Figure 3. The MSS method was devised in order to effectively describe qualitative research data collected from field research such as video observation studies (Choi et al., 2008). The modular information structure of the MSS format enables design researchers to analytically represent complex situations as well as to systematically identify cause-effect relationships among information cells. Columns can be flexibly organized for incorporating design information elements of concern while rows represent a chronologically ordered series of discrete/continuous events. In order to describe observed user-product interaction, this research divided the columns into user-side and product-side information. In the analysis of this experimental data, critical factors for understanding users' learning process were included in the columns, such as motivation, existing knowledge, interpretation, action, and new knowledge.

4. Results and Discussion

4.1. Knowledge Process of Different Groups

Users' knowledge acquisition and utilization patterns in product use were found to be highly dependent on users' levels of operation and domain knowledge.

Design information elements of concern

Time / Sequence

Time	User-side rationale				User's existing knowledge		User's action		User's new kn.		Contexts of use			System action	System-side rationale	
	Profile/ interview	Motivation: Motive	Motivation: Goal	Inten-tion	DK	OK	Interpretation	Physical	DK	OK	Social	Cultural	Physical		Function	Attribute
00:00	37-year-old house wife / Olympus user for 3 months	Wants to take a picture of the painting as a souvenir of the tour	Take a picture after turning off the flash	Wants to turn off the flash	Doesn't know what factors can influence photo quality	Doesn't know what the flash button is / how to turn off the flash							The museum doesn't allow use of a flash			Common icon design for the flash button
00:20	"I prefer to learn a new camera through trial-and-error."			Doesn't want to read the user's manual				Presses the flash button until the Flash-off is selected			User(2) lets her know what the flash icon is			Shows the Red-eye icon, then the Flash-off icon on the LCD	The camera has four modes of flash	Flash-off icon shown with texts
00:30							The flash is successfully turned off		What the flash button is / how to turn it off							

[Figure 3] Analysis tool: Modular Script Scenario

1) OpN/DmN users

At the beginning of task execution, users who did not have knowledge about either camera operation or photography often had difficulty in understanding what they should know to achieve a particular goal. In the camera study, when given the task, "Take a picture of a painting in a dark museum where the flash is not allowed," this group of users, who were previously unaware of the flash-off function, struggled in figuring out what they should do in order to disable the flash. Similarly, in the coffee maker study, some novice users were perplexed even by the basic vocabulary used in the task description (e.g. "four cups") and were largely ignorant of what knowledge would be required by the task. In addition, since this group of users generally had lower expectations of the output quality, they just stopped exploring and learning the product once they found out the particular functions necessary to complete the task.

2) OpE/DmN users

This group of users most quickly finished the tasks. They correctly determined what they had to do to complete the tasks and easily found the proper interface elements. However, since their expectation of the output quality seemed to be confined within the product capability (as they perceived it), they did not thoroughly seek better quality outcomes. Based on their ample experience and great confidence in operating a camera or a coffee maker, they quickly concluded the limitations of product capability, which were not actually correct, and stopped exploring the product within short time. For the task, "Take a picture of a painting in a museum," although users in this category promptly took a picture using the Auto shooting mode and the flash-off function, they could not obtain satisfactory photos. Since the task asked them to take a picture in a dark condition, the pictures taken in the Auto mode without using the flash were too dark or blurry. In order to solve these problems, they should have known how to manipulate the manual features such as exposure, shutter speed, or ISO speed settings.

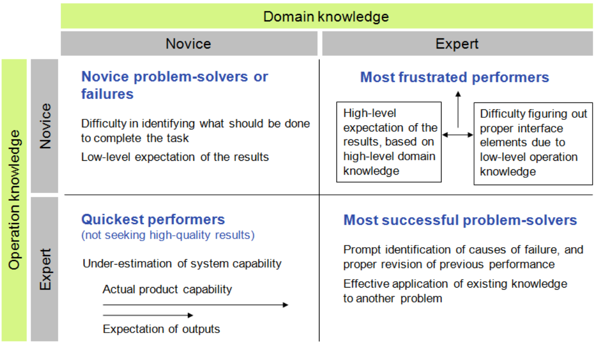
3) OpE/DmE users

This group of users, who did have both ample operation and domain knowledge, was able to most effectively apply existing knowledge to solve a new problem in the domain. In the coffee maker study, most participants were not familiar with a coffee maker that had a grinding function. While OpE/DmN users who had been accustomed to the automatic brewing function could not properly figure out how to accommodate the new factor (the granularity of coffee ground) in their coffee-making routine, OpE/DmE users understood how the new factor worked together with the other factors in making quality coffee. Although some users of this group could not make satisfactory coffee in the first observation, they promptly found out what the problem was, and successfully improved their coffee in the follow-up session.

4) OpN/DmE users

Like OpE/DmE users, this group had knowledge about problem-solving principles in the domain. However, their lack of operation knowledge made their learning process quite unproductive. While they had high expectations of output quality based on their high-level of domain knowledge, their insufficient product operation slowed their exploration and hindered them from appropriately utilizing their domain knowledge to achieve quality results. For example, in the coffee maker study, this group of users thought that they were properly controlling the amount of water and coffee and the fineness of coffee ground. However, since they could not appropriately control the menu options, they failed to make satisfactory coffee. Based on the two case studies, it seems clear that users' ample knowledge about the target domain of a product would not guarantee a quality outcome of interaction if they do not have appropriate support regarding product operation.

Figure 4 depicts the comparison among different interaction and learning patters of four different users groups.



[Figure 4] Comparison among different user groups' interaction patterns

4.2 Factors of Users' Learning in Interaction

In the section 2.2, some factors of users' learning experience were defined, based on theoretical reviews. Then, the factors are re-examined by analyzing the empirical data.

1) User expectation (Ex)

Users initially have certain expectations of the output quality and the product performance, based on their motivation in using a product, and their levels and types of knowledge. In the case studies, users' knowledge process through interaction were highly affected by the levels of expectation they had. Their expectations evolved as they acquired more knowledge about the product operation and the domain through the interaction. Whether users estimated the capability of a product much higher or lower than the actual capability, both cases were found problematic. Participants who had expectations beyond the actual functionality of the camera became disappointed with the limitations of the camera after extended exploration. Those who had underestimated the camera easily compromised their pursuit of higher quality pictures by accepting the underestimated camera capability before learning its full potentiality.

2) Availability of knowledge (Av)

It is critical for users to have knowledge necessary to achieve a goal in interaction. If they do not have their own knowledge, they need to obtain knowledge from other sources. In the case studies, users' knowledge acquisition took place through trial-and-error by referring to a user's manual or by asking their partner's opinion. Another need found in observation was about users' time-efficient knowledge acquisition. Most users reluctantly read the user's manual only as a last resort in resolving a problem. They thought reading the manual would be too time-consuming even if it might ensure their knowledge acquisition.

3) Types of knowledge (Tp)

Although OpE/DmN and OpN/DmE users had expertise in either product operation or domain of concern, neither group could achieve quality outcomes. OpE/DmN users, who were good at operating the automatic functions of a product, did not pursue further learning for better quality. On the other hand, OpN/DmE users, who had higher standards of quality based on their expertise in the domain, struggled with their lack of operation knowledge in their efforts to satisfy their high expectations. Therefore, it is clear that appropriate acquisition and manipulation of both types of knowledge is important for users to accomplish quality outcomes. Domain knowledge was particularly critical to encourage participants to have higher levels of expectation and to help them produce better quality outcomes and apply knowledge to different situations. However, current products and user's manuals do not give appropriate user support for acquiring and manipulating domain knowledge.

4) Appropriateness of knowledge (Ap)

In the observations, users' incorrect knowledge or misinformation often hindered their learning and interaction processes. A participant who believed that the coarser coffee ground was, the stronger the coffee would be did not succeed in making the desired quality of coffee even in the second round. In some cases, participants were further confused by incorrect information offered by their partners or searched from Internet. Although the user's manual provided correct information about product operation, sometimes users could not effectively utilize it because they had difficulty in identifying the most relevant information to their particular problems.

5) Representation of knowledge (Rp)

Representation methods of knowledge are critical for users to have positive learning experience in interaction. In the cases where knowledge representations embedded in the camera or coffee maker were not well matched with users' existing mental models, users could not achieve satisfactory outcomes and their learning experience was deteriorated. For example, DmE users in the coffee maker study thought that the amount of water and coffee were separately adjustable in making desired coffee taste. While the users thought the number of cups on the control panel measured the amount of water, it actually determined the amount of coffee that would be ground to yield a standard cup of coffee. This representation of coffee-making mechanisms did not fit with expert users' mental models. In the digital camera study, the flower icon referring to the Macro mode (a close-up mode) was not easily recognized, especially by operation-novice users. In addition, the way the user's manuals represented knowledge did not often fit with users' expectations. For example, while the camera users needed knowledge for operation procedures for task execution, the manual presented only the structure of menu options available in the camera.

6) Manipulability of knowledge (Mn)

Manipulability is considered to be users' meta-knowledge operation involved in monitoring and evaluating their activities. From the observations, it was clear that how effectively users controlled the factors involved in interaction was key to successful goal achievement. Such manipulability highly depended on whether users had enough domain and operation knowledge. OpN/DmN users' difficulty in identifying what kinds of knowledge they had to use or obtain to achieve a goal is an example of manipulability problems. Although OpE/DmN users were better in estimating how they should operate, they did not have clear ideas about what factors would

Factors	Parameters	Related issues
User expectation	product capability	- Much higher or lower expectation for product capability
	Output quality	- Low motivation for learning and seeking quality outcomes
Availability of knowledge	Sources	- Difficulty in figuring out where they can find particular knowledge they need
	Time/timing	- Time-inefficiency in searching for knowledge
Types of knowledge	Operation knowledge	- Inappropriate user support in obtaining knowledge for product operation
	Domain knowledge	- Lack of user support in obtaining knowledge for the domain of concern
Appropriateness of knowledge	Reliability	- Confusion due to incorrect knowledge from external sources or in users' memory
	Relevance	- Confusion due to correct but irrelevant information presented
Representation of knowledge	Internal	- Users' misinterpretation of external information, based on their incorrect or ineffective application of existing mental models
	External	- Unexpected product actions, which may not correspond to users' mental models
Manipulability of knowledge	Self-monitoring	- Difficulty monitoring their performance during product use and learning processes - Lack of the feeling that they are properly leading the interaction
	Self-evaluation	- Difficulty identifying what factors caused the current problems and how to improve the current output - Lack of confidence that they are properly leading the interaction
	Transferability	- Difficulty applying existing knowledge to new problem-solving

[Figure 5] Factors of users' knowledge processes in interaction shape their output quality and how to improve the output quality by manipulating the factors. Furthermore, users' lack of self-efficacy or sense of control seemed to reduce their motivation and activeness in maintain their interaction and learning.

As mentioned in 2.2, these factors introduced above are closely interrelated. The findings from the observational data are consistent with the research assumption that the interplay among these factors can positively or negatively influence users' learning process and as a result, their performance in and satisfaction with product use. Although the experimental studies attempted to identify participants' motivations and patterns of product use in their daily lives, the addition of more open-ended and long-term observations may provide richer information for understanding people's learning experience.

5. Conclusions

This research seeks a methodology for supporting product/system designers in developing a product that can help users more actively expand and manipulate their knowledge through interaction in order to achieve quality outcomes and make the product use richer. In this particular paper, models of users' knowledge construction in interaction are proposed. Then, how users' operation knowledge and domain knowledge affect their learning process is investigated through two case studies: a coffee maker study and a digital camera study. The collected data were analyzed according to four different user groups and six factors of knowledge construction. From the observation results, it is clear that users need to acquire and properly manipulate not only operation knowledge, but also domain knowledge in order to achieve quality outcomes through interaction.

Therefore, a product should be designed for supporting users' domain knowledge development and manipulation. The future development of this research will include an investigation of more concrete and practical mechanisms of learning enhancement and the implementation of a design methodology by which designers can effectively and efficiently apply the mechanisms to their design practice.

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