

Strategic Knowledge of Computer Applications: The Key to Efficient Computer Use

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Abstract

There are many initiatives to train people in using Information and Communication Technology but several international studies have shown that despite adequate computing experience, many users do not make efficient use of computer applications. This may be caused by a lack of strategic knowledge that is difficult to acquire just by knowing how to use commands. Research by Bhavnani and others indicates that the efficient use of computers requires task decomposition strategies that exploit the capabilities offered by computer applications, and they maintain that these general strategies can in fact be built into an instructional framework. The researcher replicated Bhavnani's work with technologically disadvantaged South African tertiary students in order to ascertain whether the instructional framework was effective for students with very different backgrounds, and also to ascertain whether it was sufficiently robust to be successfully implemented at a distance from the original designers. Transfer of strategic knowledge across computer applications was also investigated. An experimental research design was followed with experimental and control groups of Engineering students. The results showed that several of the students could be taught to recognize and exploit strategic knowledge. It is also apparent that the command instruction given to the control group was not sufficient for them to acquire such strategic knowledge. The results also indicated some transfer of strategic knowledge across the applications.

Keywords: Computer training, ICT literacy, Strategic knowledge, Innovative instruction

Introduction

The human-computer interaction (HCI) research community has focused on the design of computer interfaces that reduce the time taken by end users to learn computer applications. This approach is intended to enable users to perform tasks quickly and it assumes that thereafter they would improve their computer skills by exploration and experience. However, several studies on the use of computer applications (Bhavnani & John, 1997; Thomas, 1998, 2000) have shown that, even after a considerable period of experience and exploration, many users do not progress to use computer applications efficiently. Students studying computer literacy at the institution reported

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on in this paper also seemed to show very little progress in the efficient use of MSOffice applications. These students generally come from disadvantaged backgrounds and very few had any computer exposure prior to their freshman year. They were especially in need of positive learning experiences that would help them understand how to use computer tools efficiently and thus en-

able them to advance swiftly from novice to competent users. A possible intervention was suggested by the results of research undertaken from 1997 to 2001 by Bhavnani and his colleagues that indicated that the efficient use of computer applications requires strategic knowledge in addition to command knowledge.

This paper begins with a description of Bhavnani's instructional approach to teaching the strategic use of complex computer systems; continues by hypothesizing as to whether such an approach could be used to fast-track students with low-level entry computer skills into effective computer users and then goes on to describe an experimental design to test the hypothesis and its results.

Strategies for Exploiting the Power of Computers

Bhavnani, Reif and John (2001) identified a set of strategies that can be used across computer applications such as word processors, spreadsheets, CAD systems and Web page design. They maintained that such strategic knowledge is difficult to acquire spontaneously even though the interface that users are interacting with is good. However, they claimed that users can be explicitly taught to use these strategies. They identified efficient and general strategies for using computer applications and the components of the strategic knowledge required for using them. These strategies are shown in Table 1 below.

Bhavnani et al. have also developed a framework for teaching such strategic knowledge and have used it successfully in controlled studies with freshman students initially at Carnegie Mellon University and subsequently at the University of Michigan and the University of Western Australia (Thomas, 2000). The results of these experiments indicate that such an instructional framework enables students to learn strategies for using computer applications efficiently and has the potential for enabling the transfer of this strategic knowledge across different applications.

Table 1: General and efficient strategies to exploit four powers of computers.

Iteration
1. Reuse and modify groups of objects 2. Check original before making copies 3. Handle exceptions before/after modification of groups
Propagation
4. Make dependencies known to the computer 5. Exploit dependencies to generate variations
Organization
6. Make organizations known to the computer 7. Generate new representations from existing ones
Visualization
8. View relevant information, do not view irrelevant information 9. View parts of spread-out information to fit simultaneously on the screen

(Bhavnani, Reif & John, 2001, p. 230)

Iteration strategies exploit the iterative power of the computer by allowing the user to collect together objects that need to be modified and to delegate the task to the computer. For example, if many files require the same address to be changed it is more efficient to select and copy the changed address to the files rather than type it out in each one. When making many copies of this changed address, it is important that the original is checked for accuracy before copying it to all the files. If only one of the files requires that the city of the address be in upper case, it is more efficient and less error-prone to copy the address as-is to that file and only then to modify the case of the city.

“Propagation strategies exploit the power of computers to modify objects that are connected through explicit dependencies. These strategies allow users to propagate changes to large numbers of interconnected objects” (Bhavnani, 2001, p. 230). An example of Strategy 4 (Make dependencies known to the computer) would be to link formulae to dependent data in a budget spreadsheet so that if any of the formulae, say the formula for calculating contribution to an investment fund, needs to be changed the modification can propagate throughout the dependent data.

Organization strategies leverage the power of the computer to organize data into an explicit form that is represented internally in a computer and that can be easily manipulated. For example a table will maintain its form whilst its contents are changed whereas if the data had been put into a table using tabs, this might not be the case.

Visualization strategies use the computer’s ability to display selected data in a convenient way and reduce navigation time. For example, if a spreadsheet user needs to compare data at the beginning of a lengthy sheet with that towards the bottom then using split screens to view the data simultaneously is more efficient than continuous scrolling up and down.

Each of the strategies in Table 1 requires three knowledge components: command knowledge, application-specific strategic knowledge and application-general strategic knowledge. Bhavnani incorporated these three components into the instructional framework that relies heavily on teaching the knowledge components in an order that enables "the tight coupling of commands and strategies" in clearly described steps (Bhavnani, Reif & John, 2001, p. 232). Detailed specifications of this method are embodied in "teaching scripts" that are then used by the instructors during the classroom instruction. The instructors are rigorously trained in the use of the teaching scripts prior to their giving the instruction. (Details of these scripts can be found on <http://www.si.umich.edu/StrategyCourse>). All the strategies are based on the classic GOMS model of *If then...do rule*. (GOMS is an acronym that stands for Goals, Operators, Methods and Selection Rules.) GOMS, that has its foundation in cognitive psychology, has provided a useful framework for analysing human computer interactions.

In Table 2 a matrix from the above web site shows an example:

Table 2: Example of a GOMS strategy

	CONCRETE (specific strategy)	ABSTRACT (general strategy)
SELECTION RULE	<i>If</i> a Word document has a paragraph you want to refer to further down in the document, <i>then</i> move down from your present position in the document until you see it	<i>If</i> information is spread across a Word document, <i>then</i> bring the salient parts of the information together
METHOD	Move mouse to scroll bar, click and drag	Use an appropriate method to accommodate this – for example “split windows” in Word

Hypotheses

1. The researcher hypothesised that the instructional framework described above could be successfully used to teach students from technologically disadvantaged backgrounds to acquire strategic knowledge as well as command knowledge of complex computer applications.
2. Furthermore, this training approach could aid such students to transfer strategic knowledge across different computer applications.

Research Design

The study was designed to answer the following research questions:

1. Does the instructional approach enable the acquisition of strategic knowledge without detriment to the acquisition of command knowledge?
2. How robust is the instructional method when implemented at a distance from the original designers with students with very different backgrounds?
3. Is there transfer of strategic knowledge across computer applications?

The experiment was conducted in the context of an existing semester end-user computing course for first year Engineering students. The students were taught basic computer knowledge and Windows followed by MSWord and MExcel. The students were not taught “styles” nor “zooming in or out” as these sections were not part of the regular EUC course. Bhavnani's instructional method was introduced in the latter two sections of the course. The Civil Engineering class of 40 students were taught using the instructional framework encompassing the components of strategic knowledge described in Table 1 with the exception of Strategies 5 and 8, whilst a control group of 38 Electrical Engineering students were taught from scripts identical in content except for the omission of the strategic content. Strategy 9 (*View part of spread-out information to fit simultaneously on the screen*) was not taught in MExcel in order to test whether the students in the experimental group were able to transfer that strategy from the MSWord instruction. The same lecturer taught both control and experimental groups as a means of controlling differences in teaching style and ability.

The Instructional Framework and its Implementation

The teaching scripts used by the instructor introduced the application's commands before the strategies. The students were moved from simple tasks to more complex tasks that justified the introduction of a strategy to make the complex tasks simpler. Simple tasks are those that are designed to reinforce the student's understanding of the application's commands. Complex tasks typically would be those that involve many repetitions or are made up of many sub-tasks. An important component of the teaching scripts is the tying of the declarative knowledge of the commands to rigorous practice whereas, on the other hand, the complex tasks with their accompanying emphasis on efficient strategies demonstrate a general rule through the use of concrete examples. In order to facilitate the teaching of the general strategies, the instructor handed out a “strategy sheet” to the students. This sheet is built up application by application. An example of such a handout is shown in Table 3 below. The instructor used this strategy handout to relate the general form of the strategy to the example she was teaching. She also emphasised the transfer of the strategies across the two applications. Strategies 5 and 8 were not taught to the experimental group and Strategy 9 was not taught in MExcel.

In order to ensure that the lecturer understood the instructional framework, the researcher drew up a companion document to the teaching scripts that explained the underlying principles and their benefits in a simple and concise manner, and that pointed out specific examples of the principles in the teaching scripts. The document was designed for inexperienced computer literacy lecturers with little or no educational training. Guided by Lanham (1990) and Langan (1993), the researcher also examined the teaching scripts for language, cultural and gender bias and ensured that they were appropriate for South African users who are not English mother tongue speakers. The researcher then gave the EUC lecturer 4 days training on how to teach the strategies from the teaching scripts. (The researcher had visited Suresh Bhavnani at the University of Michigan and had received training from him in employing his instructional framework. He and his team were

interested to establish whether their instructional framework was still effective when implemented at a distance from the original designers with students with very different backgrounds.)

Table 3: Strategy Sheet handed out just before MExcel Instruction

General Strategies	Advantages	Examples	
		Word	Excel
Operate on Groups		Commands: <i>Click-drag, copy, move, modify format</i>	Commands: <i>Click-drag, copy, move, modify format</i>
1	Reuse and modify group of objects	Reduces execution time and typing errors	Copy and modify existing paragraph to create a new one
2	Check original before making copies	Avoids reproducing errors	Check if paragraph is correct and complete before making copies
3	Handle exceptions last	Reduces modification time	Modify full paragraph, then modify exception
Make Dependencies Known to the Computer		Commands: <i>Styles</i>	Commands: <i>Cell referencing</i>
4	Make dependencies known to the computer	Ensures consistency during creation and modification	Setup paragraph formats to be dependent on styles when the formats need to be consistent during creation and modification
5	Exploit dependencies to generate variations	Reduces modification time	Modify style definitions to generate variations of the same document
Make Organizations Known to the Computer		Commands: <i>Tables, lists</i>	Commands: <i>Sheets, charts</i>
6	Make organizations known to the computer	Maintains organization during modification	Use lists and tables to organize related information
7	Generate new representations from existing ones	Reduces creation time and errors	Generate table from tabbed words
View Selectively		Commands: <i>Split window, new window</i>	Commands: <i>Split window, new window</i>
8	View relevant information, do not view irrelevant information	Reduces visual complexity	Zoom in to reveal more detail
9	View parts of spread out information to fit simultaneously on the screen	Reduces navigation time	Use split windows or new windows to bring relevant information simultaneously on the screen

At the end of the course, volunteers from both groups were offered a small monetary incentive to undertake a post-test specifically designed to provide opportunities for them to use 6 of the strategies shown in Table 1. (Time allocated to the post-test did not allow for Strategy 2.) There were 20 student volunteers from the experimental group and 18 from the control group. The students were also asked to describe how they had gone about the tasks. The actions of the students during the MSWord section of the tests were observed and recorded by lecturing staff whilst the students' key presses during the MSExcel section were captured by macro recording. The students' scores on the EUC course's regular continuous assessment tasks, that test command knowledge, were analysed to ascertain whether the added strategy content had had any detrimental effect on the experimental group's acquisition of command knowledge.

Results and Discussion

In Table 4, the results of the post-test of both the control and experimental groups are set out. The first column sets out the strategy that the students could have employed. The numbers in the second and third columns reflect the percentages of students who used the strategy.

Table 4: Percentage of students in the experimental and control groups who used the general strategies in the experiment.

General strategy opportunities offered student volunteers in the post-test	Percentage of Experimental Group who employed the strategy	Percentage of Control Group who employed the strategy
MSWord		
1. Re-use and modify groups of objects	80	44
3. Handle exceptions last	65	22
4. Make dependencies known to the computer	100	66
MSExcel		
1. Re-use and modify groups of objects	39	27
7. Generate new representations from existing ones	63	47
9. View parts of spread out information to fit simultaneously on the screen	39	0

Acquisition and Appropriate Use of Strategic Knowledge

As is apparent from Table 4, the experimental group did significantly better than the control group in exploiting five strategy opportunities ($p < 0.05$ for each based on chi-squared tests). These results indicate that several of the students could be taught to recognize and exploit strategic knowledge. It is also apparent that the command instruction given to the control group was not sufficient for them to acquire such strategic knowledge.

Transfer of Strategic Knowledge across Applications

The results showed that some of the students in the experimental group did learn the general form of one strategy. As discussed above, the strategy *View parts of spread-out information to fit simultaneously on the screen* was deliberately not taught to the experimental students in MSExcel in order to test whether they were able to transfer this strategy from MSWord. Table 4 shows that 39% of the experimental students did recognize the opportunity to use "split windows" in MSExcel (Strategy 9). This does suggest that there was some acquisition of the general strategy by

these students and that they were able to use it in another application. Even though this result cannot be taken as conclusive, it is important in that if the strategy is not learned at the general level, it is unlikely that computer users will employ it in another situation. As these students were studying Engineering, the transfer of these strategies to Computer-Aided Design software is a strong possibility and would warrant further investigation.

Effect on Command Knowledge

The scores in the regular EUC tests showed that the experimental group consistently achieved slightly better marks than the control group. Therefore it can be maintained that the strategic instructional framework was not detrimental to the acquisition of command knowledge.

Robustness of the Instructional Framework

The students in both the sample groups came from very under-resourced technological backgrounds. Typically they had had no opportunity to work on a computer before as few had access to computers either in the home or at school. This had an effect on their learning environment as they had to battle with the unfamiliarity of both the keyboard and mouse. Also, the institution was under resourced with regard to computer laboratories so the students were not given time outside regular classes to practice what they had been taught. Despite these disadvantages, several of the students were able to acquire and exploit the strategic knowledge taught them by using Bhavnani's instructional framework. This certainly attests to its robustness when used at a distance from its original designers.

Conclusion

Access to ICT not only means possession of the necessary computers, software and connections, but also of the basic skills for using them effectively and efficiently. This latter aspect might prove to be ultimately the biggest barrier to participation of students from the developing world in the knowledge society. It is vital that students are not just given training in the basic computer application packages and Internet navigation but that they are taught to use their computer skills in innovative and effective ways to solve real-life problems. Bhavnani's method of teaching the strategic use of complex computer systems provides a promising alternative to traditional computer literacy instruction that typically focuses on command knowledge. It has the potential to ensure that novice users do progress to use computer applications in an efficient manner that exploits the powers of the computer particularly those of iteration, propagation, organization and visualization described in Table 1 above. The researcher maintains that this approach will have the dual effect of enabling students with low-entry level computer skills to employ general and efficient strategies for using applications effectively, as well as raising their computer self-efficacy to a level that will ensure their continued confidence in the face of technological change.

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Biography

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