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ABSTRACT

This study investigated the educational implications of having a group of 17 first-year New Zealand nursing students develop a medical expert system. Goals of the study were to determine whether, in the process of developing the expert system, the learners could: (1) acquire a more in-depth understanding of the specific subject domain under study (namely, how to identify alcoholic patients); (2) develop a more complex set of problem solving strategies; and (3) acquire conditional reasoning skills. An ethnographic case study approach was adopted. The learners participated as a whole class in six sessions over a period of 10 weeks, for a total of 10 contact hours. In addition to whole class sessions, they met in small groups to interview subject matter experts. Participants then met as a whole class to share their information and to construct rules for the knowledge base of the expert system. Both quantitative and qualitative measures were used to describe how the learners could use computers to acquire knowledge and thinking skills in a group learning context where computers were used as tools. Data were collected using the following instruments: pre- and posttests to measure gains in reasoning abilities; student worksheets to solicit information on the participants' problem solving strategies and knowledge representation; students' logs; and questionnaires to collect information on students' background, knowledge acquisition, and attitudes towards the expert system as an instructional aid. Due to the preliminary nature of the study and the short time frame, no claim was made as to the extent of the improvement in problem solving and reasoning skills; however, the results clearly indicated that expert systems can be used to enhance the development of certain reasoning skills and also to facilitate the acquisition of a deeper understanding of the subject domain under study. (6 references) (GL)

Acquiring Expertise and Cognitive Skills in the Process of Constructing an Expert System: A Preliminary Study

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Introduction

The recent advent of microcomputer based expert system shells to the classrooms has tremendous educational potential. As suggested by some educators (e.g. Romiszowski, 1987), the use of expert systems in the tutee mode puts the learners in a problem solving and decision making position which results in a deeper understanding of the subject domain under study and also in the development of higher order thinking skills. However, little research has been conducted to document the implementation of expert systems in classrooms; and its cognitive and metacognitive implications have not been adequately investigated. The present study aimed to investigate the educational implications of constructing a medical expert system by a group of New Zealand nursing students. More specifically, this study aimed to evaluate, in the process of developing this expert system, whether the learners could: (a) acquire a more in-depth understanding of the specific subject domain under study (namely, how to identify alcoholic patients); (b) develop a more complex set of problem solving strategies; and (c) acquire conditional reasoning skills. It was not expected that the finished product would have any commercial values.

It is now well documented in the literature that learning takes place when a learner engages actively in the construction of his/her knowledge (Shuell, 1986). An important task for the teachers is therefore to provide a learning environment which facilitates the active acquisition of knowledge. Classroom expert system oriented projects could be conducive to the active acquisition of knowledge and skills by the learners. To build an expert system, learners need to understand how knowledge is structured in the computer program. As well, in order to solicit expert information to construct the knowledge base, learners need to elaborate on the problem, evaluate the goals and sub-goals to be achieved, and monitor the knowledge needed to achieved these goals. Furthermore, to utilize the expert information obtained from interviews, they have to interpret and understand how the experts represent and use their subject domain knowledge to solve the problem. This process forces the novice learners to reflect upon their own existing shallow knowledge structure and create new structure to accommodate the multilevel expert knowledge (Bereiter & Scardamalia, 1986). The rule based structure of the expert system shell provides a cognitive tool for the learners to structure the new knowledge. This whole exercise facilitates a more in-depth understanding of the specific knowledge domain under study, as well as the acquisition of the more complex and efficient problem solving strategies. Also, since conditional rules (If...then) are used to represent knowledge in the expert system, the exercise could enhance the conditional reasoning ability of the learners.

Method

Subjects

17 first year nursing students (15 females, 2 males) from a New Zealand city polytechnic participated voluntarily in this study as part of their computer awareness course. Prior to this study they had received instruction in word processing and database management, but had no training in the use of expert systems. They had no formal training in logic or thinking skills. 7 students dropped out during various stages of the study and data collected from 10 students were included in the final analysis.

Instruments

Micro-Prolog and an expert system shell called Augmented Prolog for Expert Systems (Apes) running on the IBM PC were used in this study. Micro-Prolog, a computer language based on predicate logic, is a version of Prolog (PROgramming in LOGic) developed for interactive use on microcomputers (Micro-Prolog Reference Manual, 1985). Apes augments micro-Prolog with features which are characteristic of expert systems and therefore could be used as an expert system shell for constructing logic based expert systems (Hammond & Sergot, 1984).

Procedures

The learners participated as a whole class in six sessions over a period of 10 weeks in 1988, for a total of 10 contact hours. Other than the whole class sessions, they also met in small groups to interview the experts and also worked on the interview transcripts for 3 to 4 hours. In the first three sessions instruction was given to the participants on the operation of the expert system shell and on general problem solving strategies. An expert was also invited to talk about alcoholism so that the participants had some background knowledge on the subject domain before conducting their interviews. Reading materials on interviewing techniques were also provided. After having interviewed the experts the participants met as a whole class to share their information and construct rules for the knowledge base of the expert system. The rules were coded by the researcher in order to save time. Then the expert system was implemented and validated by the whole class.

Data Collection

An ethnographic case study approach was adopted in this study. Both quantitative and qualitative measures were used to describe how the learners could use computers to acquire knowledge and thinking skills in a group learning context. Data were collected in the following ways:

1. Reasoning Tests - Two parallel sets of conditional reasoning tests were administered to the participants, one at the beginning and the other immediately after the study to

measure gains in reasoning abilities. Eight forms of conditional arguments were included in these tests (see Figure 1).

Figure 1: Eight Forms of Conditional Arguments

Form	First premise	Second premise	Conclusion	Logical validity
1	If p, then q	p	q	Valid
2	If p, then q	p	not q	Invalid
3	If p, then q	not p	q	Invalid
4	If p, then q	not p	not q	Invalid
5	If p, then q	q	p	Invalid
6	If p, then q	q	not p	Invalid
7	If p, then q	not q	p	Invalid
8	If p, then q	not q	not p	Valid

In each test there were 64 sets of three statements, most of them selected from popular logic textbooks (Taplin & Staudenmayer, 1973). For example, a typical question might have been:

(a) If I am X, then you are Y.

(b) I am X.

(c) You are Y.

The participants were told that statements a and b were known to be true and they were required to evaluate whether statement c necessarily followed from statements a and b. They were also asked to state how confident they were with their answers.

2. Student Worksheets - Three student worksheets were administered to solicit information on the participants' problem solving strategies, how they represented their knowledge, and their understanding of the experts' knowledge structure.

3. Students' Logs - Each student was requested to keep a log recording what they had learned in each session.

4. Questionnaires - A questionnaire was administered at the beginning of the study to collect background information. Another questionnaire was administered at the end of the study to collect information on knowledge acquisition and also on the learners' attitudes towards the use of the expert system as an instructional aid.

Results and Discussions

Knowledge Acquisition

One of the objectives of this study was to investigate whether learners could acquire a deeper understanding of alcoholic problems, especially on how to identify alcoholic patients in a hospital ward by constructing an expert system. At the end of the study a simple expert system to assist the learners to identify alcoholic patients was built. This expert system had 35 rules and exhibited a hierarchical knowledge structure (see Figure 2).

Figure 2: Knowledge Base of the Expert System

```
                    ---------------------------------
                            Alcoholic Patient
                    ---------------------------------
                    |          |          |          |
  ----------------  ---------  ---------  -----------
  Related Illnesses  Symptoms   History   Self-report
  ----------------  ---------  ---------  -----------
          |                |
    ----------------   ------------------
    Liver Damage, etc.   Hallucinations, etc.
    ----------------   ------------------
```

This expert system was a rule-based system where knowledge was represented by rules. In micro-Prolog, a rule consists of a conclusion and at least one condition. It has the form:

Conclusion if condition and condition ...

Users could query the expert system by asking a question. For example:

Confirm(Peter is an alcoholic)

The inference mechanism of the system would activate (fire) the rules and perform the deduction (inference). The conditions of the rules were evaluated and additional information were sought from the users. The users were asked for the medical history of the patient, and also the symptoms and related illnesses the patient had. Based on these responses, the system could deduce an answer and report on the status of the patient. Figure 3 lists a sample of these rules.

Figure 3: Sample Rules of the Expert System

X is most likely an alcoholic if

X has previous history of dependency and

X has related illnesses and

X has symptoms

X is probably an alcoholic if

X has related illnesses and

X has symptoms

X has related illnesses if

X has liver damage and

X has memory defects and

X has infections

Representing expert knowledge in rules and breaking them down into inter-related components required more than a surface understanding of the subject domain. From the rules they have constructed, it was evident that the participants of this study had acquired the knowledge of identifying alcoholic patients. It was further evident from the participants' verbal reports and responses to the worksheets and questionnaire administered at various stages of the study that they could better comprehend the complexity of the problem and had a deeper understanding of the subject domain by constructing the expert system. They could also reflect upon the knowledge structure of the experts and elaborated on their own knowledge structure. There was also a clear indication of a deeper level of understanding on the subject domain when the participants were asked to design a similar course to teach their fellow classmates at the end of the study. Of those who had completed the study, specific guidelines as to the course content and strategies to be employed were reported. One of the participants gave the following outline:

'1. Firstly give several definitions on alcoholism so that the student finds a full detailed definition they can use.
2. Identify reasons possible for alcohol abuse to take place.
3. Then discuss signs and symptoms of alcoholism giving them a ranking from most common and likely [to] least common.
4. Discuss permanent damage done by alcohol abuse.
5. Talk about method of diagnosis used when dealing with alcoholism.
6. Investigate treatments available to help an alcoholic, and long term measures that are/need to be taken to prevent alcohol abuse happening again.'

From this course outline it was clearly shown that this participant could systematically break down the course content into related sub-topics. Apparently, her level of understanding of the course structure was shared by another participant who noted that in designing the course on alcoholism the "main problems [should be] broken down into sub-goals showing inter-relationship between factors". She further explained that "breaking down a problem facilitates understanding, and linking factors helps objectivity, i.e. working out assessment priorities for treatment.. "

On the other hand, those participants who did not complete the study only gave partial and superficial answers to these questions which reflected their lack of comprehension of the complexity of the problem. They also did not use any specific problem solving strategies in planning the lessons.

Learning did not take place only in the actual construction of the expert system. Interviewing the experts and group discussions also facilitated learning. For one participant, transcribing the interview tapes was a learning experience.

> 'During transcription of taped interview I felt I only then began really understanding alcoholism - going back and back over gives you a strong picture on the subject and pushes you further to ask questions.'

It seemed that the process of interviewing the experts had forced the participants to think about the problem carefully so as to be able to ask relevant questions and respond to the experts' answers. Transcribing the interview tapes also allowed the participants the opportunity to think about the problem more deeply.

Problem solving strategies

It was noted in this study that in order to construct rules for the expert system, the participants need to break down the expert knowledge into components and also need to build a hierarchy of inter-related knowledge structure. In this process not only could the participants acquire a deeper understanding of the subject domain, and also elaborate their own knowledge structure, but could also acquire some general problem solving skills in organizing and categorizing information. It was clear from the worksheets and questionnaire that these skills had been enhanced. When the participants were asked what procedures/strategies would they follow when they solved problems, the following reports were made:

> 'Identify the goal...If the goal was too large, break it down into subgoals and work up from there.'
>
> 'A hierarchy...use of sub-groups, linking, investigating, validating '
>
> '...look closely at the problem...making sure fully understand the meaning of it...seek further knowledge to relate ideas of possible solutions being appropriate using the supplied information...I would break it up into the simplest form...I would endeavour to relate all the ideas...in working towards a goal.'
>
> 'Break it down in a logical manner by dividing it into sections and then checking to see if these are

inter-relating factors...'

With regard to the transfer of skills, the participants were asked whether what they had learned in the study would be useful in other subject domains. They reported that since the study was a problem solving exercise it would be useful in other domains. One participant noted:

> '...the problem solving strategies we have learned fit well into an important part of nursing practical care called nursing process...can be a foundation for our use...'

And they also realized the importance of thinking (understanding) in the learning process. One participant noted:

> 'I have learnt how easy it is to take so much information for granted - in lectures you can see it/hear it/ it's just rote learning...it's not really thinking and it's when you're truly actively using your thinking...that you can remember something because you had to think about the topic. When you understand something only then can you add on and build onto the previous knowledge then it has significance.'

And the exercise helped them to think. Another participant wrote:

> '...it has given me the freedom to think clearly, to really look at something and make myself...check all the possibilities not just view it literally...I

> found that you can look at problems framing a pyramid analogy, you don't have to stick to one method for a life time, many ways to do it.'

Which was shared by a third one:

> '...it allows you to have an open mind approach to other problems and to other's problems.'

Conditional Reasoning

As reported in the previous section, the expert system designed in this study was a rule-based logical system. The rules in the expert system were all conditional arguments. Constructing these rules and subsequently validating and querying the system was a good training exercise in conditional reasoning for the participants. The explanations provided by the system made the reasoning process more transparent and further enhance understanding. A typical example of querying the system might have been:

rule: If X is sick, then X sees doctor

user: Peter sees doctor?
expert system: Is it true that Peter is sick?
user: Yes
expert system: Yes, I can confirm that Peter sees doctor
user: why?
expert system: To deduce Peter sees doctor
I used the rule

X sees doctor if X is sick

I can show Peter is sick

user: Peter sees doctor?

expert system: Is it true that Peter is sick?

user: No

expert system: No, I cannot confirm Peter sees doctor

user: why?

expert system: In trying to prove Peter sees doctor

I tried the rule

X sees doctor if X is sick

I cannot show Peter is sick

What the participants could learn from the explanations given by the system was that in a conditional argument when the antecedent (Peter is sick) was affirmed, it would be valid to affirm the consequence (sees doctor). But when the antecedent was denied, it would not be valid to affirm or deny the consequence (whether Peter sees his doctor). The feedback provided by the expert system could stimulate a lot of discussion and the relationship between the conditions and conclusions of conditional arguments would be made clear to the learners.

In this study two parallel sets of reasoning tests were designed to measure the effects of this exercise on the conditional reasoning abilities of the participants. A paired t-test was conducted on each of the eight forms of conditional arguments (eight questions each) in the two reasoning tests. Significant improvements were identified in forms 4 ($t=2.51$ and $p<0.05$) and 7 ($t=5.66$ and $p<0.01$). It was noted that the form 4 conditional argument (denying the antecedent, affirming the consequence) was one of the two forms that the participants had difficulty to understand and scored poorly (the other one was form 5, affirming the consequence, affirming the antecedent). Although the improvement in this form of argument was not drastic (average pretest score = 0.67, posttest score = 2.8), judging from the limited amount of time the participants had spent in using the expert system (about 5 hours), the improvement was impressive. The participants also showed improvement in form 5 (pretest score = 1.3, posttest score = 1.8), but the result was not significant ($t=0.43$, $p=0.667$).

Conclusions

This study proposed a computing learning environment conducive to the acquisition of subject domain knowledge and certain problem solving and reasoning skills. An ethnographic case study approach was adopted to describe the learning process taken place in a group setting where computers were simply used as tools. The focus was not in developing a product, in this case an expert system, but the process in which learners could interact with one another in deepening their understanding of alcoholism. Due to the preliminary nature of this study and also the short period of time no claim was made regarding the extent of the improvement in problem solving and reasoning skills in this study. However, it was clearly seen from the results that expert systems could be used to enhance certain reasoning skills, and also in the acquisition of deeper understanding of the subject domain under study.

The use of expert systems in the classrooms has tremendous promise in the acquisition of expertise and in the teaching and learning of problem solving skills. However, it is noted from this study that the instructional procedures employed in an expert system oriented project need to be carefully designed so that the participants could have a sense of control and ownership throughout the learning process. It is also very important to integrate the expert system project into the participants' curriculum so as to facilitate applications. To allow adequate preparation for the interviews and to assimilate and elaborate on the knowledge acquired required a lot of discussions which may not be feasible if such a project is only treated as an extra-curricular activity. It is labour intensive and time consuming, especially when the participants have little computing experience and knowledge on the subject domain. The major limitation of this preliminary study was the inadequate attention paid to the time factor. If the study was conducted when the participants' final examinations were farther away, the drop out rate would have been greatly reduced. Also, had it not been due to the inadequate amount of time spent in various stages of the study, e.g. in the actual construction of the expert system, cognitive outcomes could be better documented and a more sophisticated expert system could have been built.

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