

On Expert System as Educational Trainer

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This paper describes the way in which an expert system plays an important role in computer aided education. A system aiding a student makes a decision about a subject (product) in "Practice in Woodworking" is taken up for discussion, as a concrete example. A system is developed so as to suggest a practice subject which reflects sufficiently not only the expert's (instructor's) knowledge but also a producer's (student's) personal interest etc. and so as to show a concrete image of the subject by displaying its sketch drawing. This system was evaluated on 7 items and obtained sufficiently high scores. Especially, it became obvious that its value as an educational trainer is in many ways excellent. In other words, it was suggested that a user is able to comprehend an expert's thought, to analyze the difference in thinking processes between the expert and the user and to review the contents of study items which are needed in the comprehension of a thinking process, by learning why the question was asked and/or how the conclusion was led through a conversation with the system.

I Introduction

An appropriate correspondence is required in various fields, in response to such a present situation conditioned by ① the high efficiency and the inexpensiveness of a personal computer, ② the diffusion of a personal computer network accompanied by a release of a communication market, ③ and the advanced technetronic society. In the field of education, computer aided education that is expected to enforce individual, open and modern education is worthy of attention again and seems to be gradually infiltrating school education, company education, home study and life study. It is conceivable that the practical use of a personal computer in school education is represented by two phases; one is a study based on coursewear (it seems that the study in a drill mode is the most popular) and the other is a study based on educational material such as a computer graphics simulation.

The research in "Artificial Intelligence" started, that tries to construct an intelligent activity of human beings in engineering terms, together with the birth of a computer. In an application field of "Artificial Intelligence" such as machine translation, image processing, robot etc., an expert system has mostly practical uses. An expert system is able to be utilized

in an educational phase which differs from the two phases mentioned above if the system is able to answer user's questions; why the system asked such a question or how the system got the conclusion.

In this paper, the authors developed an expert system that assists a user trying to decide a subject in "Practice in Woodworking" by using the Japanese expert shell "Sogen", and will clarify what kind of role the expert system plays in computer aided education.

II Expert system and Expert shell

An expert system implies an intelligent program, in which an expert's special knowledge in a particular field is constructed as rules, and which solves a problem by using rules as if an expert would. In other words, an expert system is composed of the Knowledge Base and the Inference Engine as shown in Figure 1. A knowledge engineer arranges an expert's fragmentary knowledge and stores them as rules in the Knowledge Base. The Inference Engine leads the problem to the conclusion by combining rules.

The most important problem is how to express knowledge because the incorporation of an expert's knowledge to the Knowledge Base with some sort of systematic form is needed. There is the production rule method to express knowledge. This rule consists of "Assumption (if.....)" and "Conclusion (then.....)", and a set of rules composes the Knowledge Base in Figure 1. The production rule is characterized by the following properties. ① The compre-

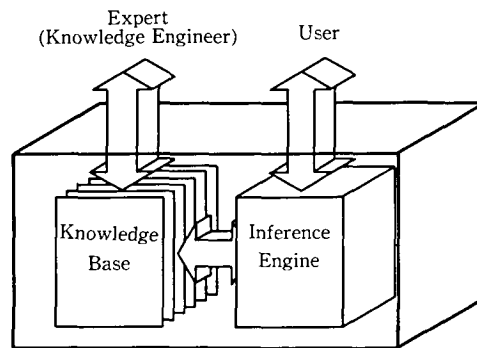


Figure 1 Expert system

hension is intuitive because the production rule is quite agreeable to a human thinking process and also it is easy to systematically organize knowledge. ② The modular nature of knowledge is excellent, therefore a confusion when a system is expanded is avoided because an addition or a change of knowledge is quite easy. ③ Such characteristics as so-called "an explosion phenomenon peculiar to a combination" scarcely occurs as for the basis of the Knowledge Base, unlike an algorithm form, even if a combination of a condition increases [2]

A remarkable characteristic of an expert system is that the Knowledge Base and the Inference Engine are separated clearly, that is to say, an expert system in various fields is easily created by only preparing appropriate rules in the Knowledge Base. Such software called "Expert shell" as prepares the Inference Engine and the empty Knowledge Base is available. The Japanese expert shell "Sogen" is used in this paper. A user is able to solve a problem through a conversation between he/she and the system that is constructed in the shell. The system displays questions and the conclusion. The user is able to inquire why such questions are asked and how the conclusion was led, by carrying out the WHY function and

the HOW function of the system, respectively. The WHY function explains the bases of questions and also the HOW function explains how the user's answer affected the conclusion and which rules were applied to the conclusion (including interim conclusions) [2] .

III Example

The Department of Technology opens the Practice in Woodworking class. The main theme of this class is how to reflect knowledge obtained through "Woodworking I" and "Laboratory in Engineering I (a field concerned in Woodworking I)" in a practice subject (product). Usually students consult an instructor on his/her subject in the class. At this time, an instructor's advice to a student, for instance advice regarding how to bond materials or which machine is appropriate, is equivalent to an expert's one, then we may say that an expert system exists in this case. We cannot help, incidentally, say, that the sufficient correspondence is not taken in consequence of time restriction for the individual guidance. Therefore, it is desirable to develop an expert system in engineering terms, from which each student is able to receive advice whenever he/she wants. The system developed here is able to consider personal motives such as an interest, a distinction of a home or a lodging, the necessity to tidy up a room, practicality of product and so on, and also is able to consider such parameters from the viewpoint of education as are time, cost, materials, bonding methods and machines. The system prepares 63 subjects (products) as shown in Table 1 and 268 rules [3,4] . Rules are not, however mentioned in this paper for convenience sake of a space.

Table 1 Practice subject (goal)

speaker box	slipper rack	bookcase 5
cassette rack	footstool	bookcase 6
record case	legless chair	bookcase 7
audio rack	checkerboard	bookcase 8
AV board	chessboard	bookcase 9
cabinet for television	frame	bookcase 10
micro-computer rack	easel	bookcase 11
space box	accessory box	bookcase 12
magazine rack	sewing box	bookcase 13
document filing box	bench	bookcase 14
slide type folding chair	bench chest	bookcase 15
rocking chair	Work seat	bookcase 16
stool	flowerpot box	bookstand 1
hanger stand	kennel	bookstand 2
display shelf	work table	desk
tableware shelf	toolbox	writing bureau
convenience wagon	mailbox	chair
counter wagon	bookcase 1	table
service tray	bookcase 2	extra table
shoe box	bookcase 3	telephone table
umbrella stand	bookcase 4	trash basket

An instance of a conversation between a user and the expert system is outlined below.

- ① The title frame is displayed as follows.

I (this system) will help you making a decision about your subject (product) that you are going to produce in the Practice in Woodworking class. In other words, I will propose subjects (products) which are suitable to your taste and intention.

I will ask you some questions. Choose the corresponding item with cursor keys, then push the return key, please.

Now, I will execute in the following order.

- (1) First of all, I will ask you about your interest, practicality of product, your life style and so on. Then I will narrow down the range of subjects that will be proposed considering your replies to these questions and will display the result as "The conclusion based on your personal motive", if you need.
- (2) I will ask you some questions from the viewpoint of reflecting upon knowledge obtained through "Woodworking I" and "Laboratory in Engineering I" in the subject which you are going to produce. Then, I will narrow down the range of subjects just like stage (1), and will show you the result as "The conclusion based on the viewpoint of education", if you need.
- (3) Finally, I will propose to you subjects considering comprehensively the results obtained at stage (1) and (2). And also you may watch the sketch drawing of the subject, if you need.

Also, I prepare educational functions such as the WHY function and the HOW function. Use the WHY function when you would like to know why such a question was asked, and use the HOW function when you would like to know how the conclusion was obtained. So you are able to comprehend my thought and are able to analyze the difference in thinking processes between you and I, through a conversation with me. I would like to suggest that you should try to use these functions.

Then, push the f•10 key and advance to the next frame, please.

- ② Subsequently, the system asks a question* as shown in Photo 1. In this case, the user chooses the item (1).
- ③ The system asks that "The field of your interest is"
- (1) Music
 - (2) Art/Craftwork
 - (3) Literature

* The system asks only necessary questions at the time. Paradoxically speaking, the system has rules which will be never questioned according to the user's response.

- (4) Science and Engineering
- (5) Game
- (6) Others".

In this case, (2) is chosen.

- ④ The system asks whether the user's room is necessary to be tidied up or not, then choose "necessary".
- ⑤ Choose (2) for the question; (1) product for practical use, (2) decorative product.
- ⑥ Reply "home" for the question "home/lodging".
- ⑦ At this stage, the system asks whether "The conclusion based on your personal motive" should be displayed or not. When "indication" is chosen, the output frame is displayed as shown in Photo 2. In this way, the product that was suggested on the basis of a personal motive is displayed.
- ⑧ The system asks the question about the cost required to produce, then answer "from 2000 yen to 4000 yen".



Photo 1



Photo 2

- ⑨ Subsequently, the question "I want to use (1) plain, flat cut boards, (2) square columns, mainly" is posed, then answer (1).
- ⑩ "Do you use a machine for woodworking?" is questioned, then reply "yes".
- ⑪ At this stage, the system asks whether "The conclusion based on the viewpoint of education" is needed to display or not. Therefore, the output frame is displayed as shown in Photo 3, if "indication" is chosen. In this way, the user finds products in which knowledge obtained through "Woodworking I" and "Laboratory in Engineering I" is reflected. The bookcase #9 and the bookcase #10 should also be the subject in addition to these 4 subjects shown in Photo 3. However, the value of the Certainty Factor⁺ of these bookcases is 0.21, so these products are eliminated from the recommendation. This is because that the minimum value of the Certainty Factor is set up with 0.4 in this system.
- ⑫ "The comprehensive conclusion" is displayed as shown in Photo 4, after "The conclusion based on your personal motive" and "The conclusion based on the viewpoint of education" were obtained through stages mentioned above. At this stage, meta-knowledge (meta-rules) is used to control knowledge (rules).
- ⑬ Finally, the system asks whether the output frame of the sketch drawing of the proposed subject is required or not, then answer "yes".
- ⑭ As a result, the sketch drawing shown in Photo 5 is displayed as an example.

Through a conversation with the system, users are able to learn why such a question was asked at each stage ②~⑥ and ⑧~⑩ by using the WHY function and through what kind of process the conclusion was led at each stage ⑦, ⑪ and ⑫ by using the HOW function. Therefore, users are able to acquire the expert's thought, are able to review the contents of study items that were related to the subject and are able to find the difference in thinking processes between the user and the expert.

The WHY frame is displayed as shown in Photo 6, when a user tries to learn why the system asked the question shown in Photo 1 by using the WHY function⁺⁺ as an example. According to Photo 6, the user finds that making a decision about "The product that you want to produce is < choices >." is necessary for deciding "The interim conclusion (the relation between the interest and the product) < choices >". In other words, the user finds that the system requires to recognize whether the product which the user wants to produce concerns his/her interest or not, when the system infers from rule #1 (the system examines whether the rule is effective or not, in the order of rule number from #1). Furthermore, by the repetition of this procedure, the user is able to comprehend that deciding "The interim conclusion (the relation between the interest and the product) < choices >" is necessary for deciding "I will suggest to you the following products that are suitable to your interest and so on < choices >." and that deciding this rule is necessary for deciding "Comprehensively, the following products are suggested < choices >." (goal).

The HOW frame is displayed as shown in Photo 7, when the user tried to know how the

⁺ The content of the fact which we always experience is so ambiguous that the Certainty Factor is able to be added to a rule by using the value from -1.0 (complete negation) to 1.0 (complete affirmation) to express the certainty.

⁺⁺ Execute by pushing the f.1 key.

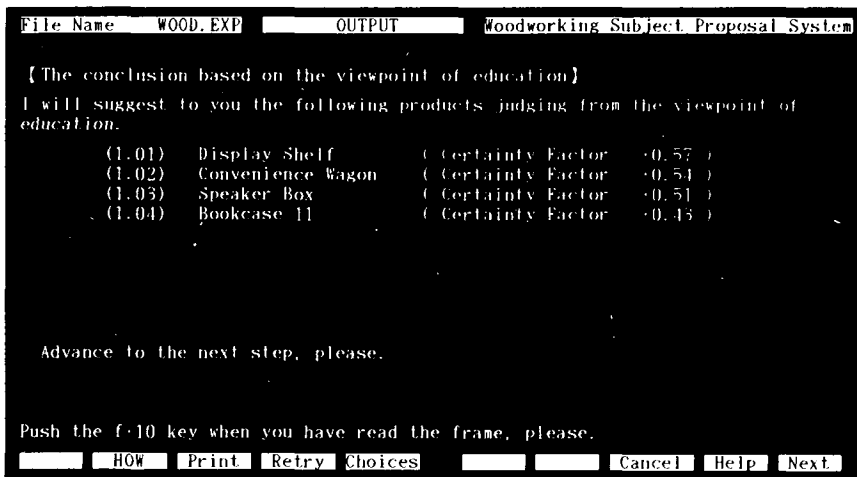


Photo 3

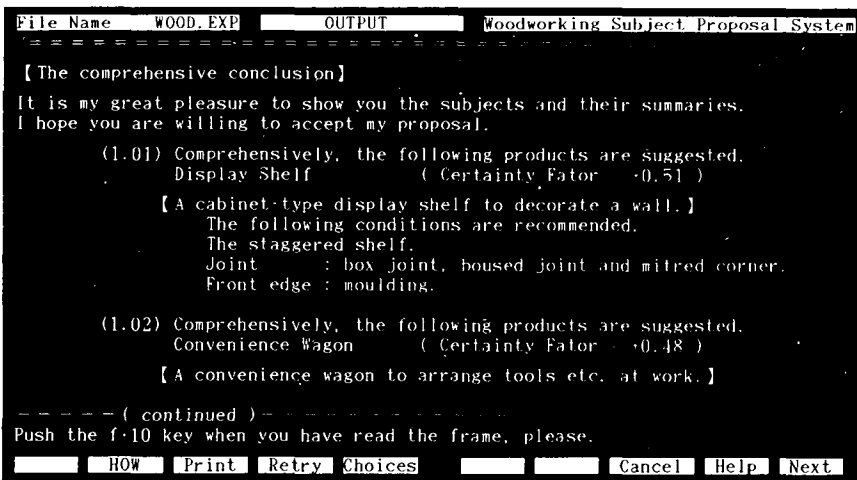


Photo 4

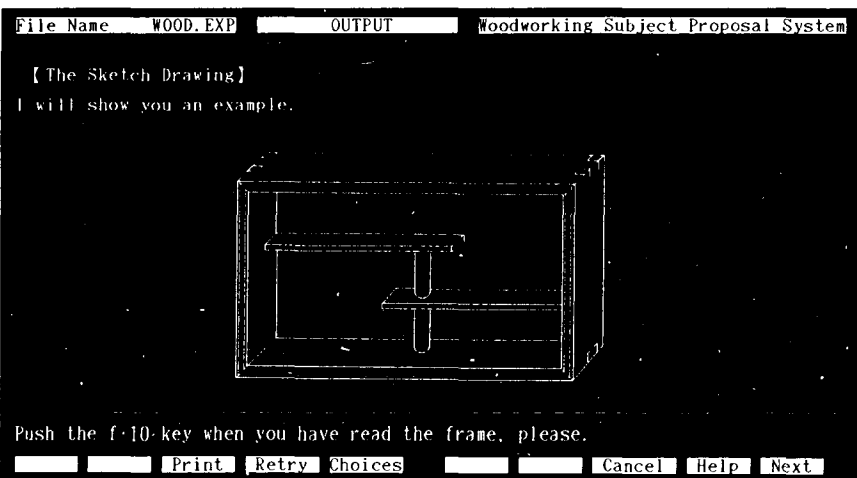


Photo 5

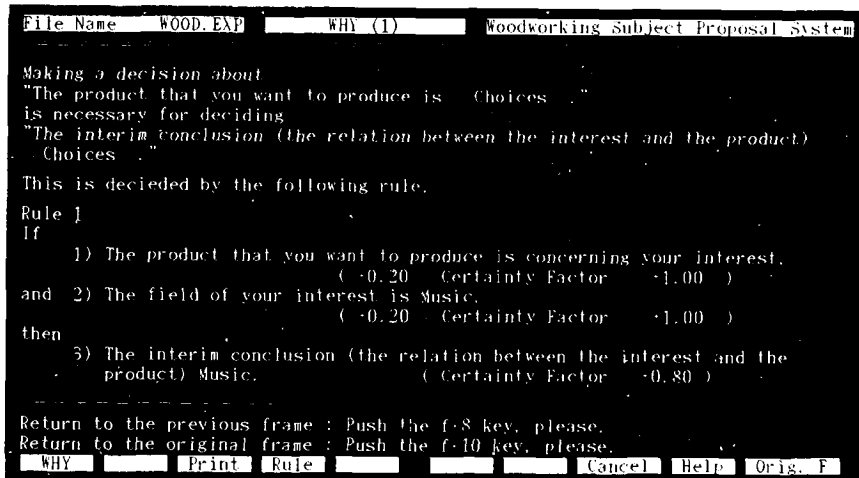


Photo 6

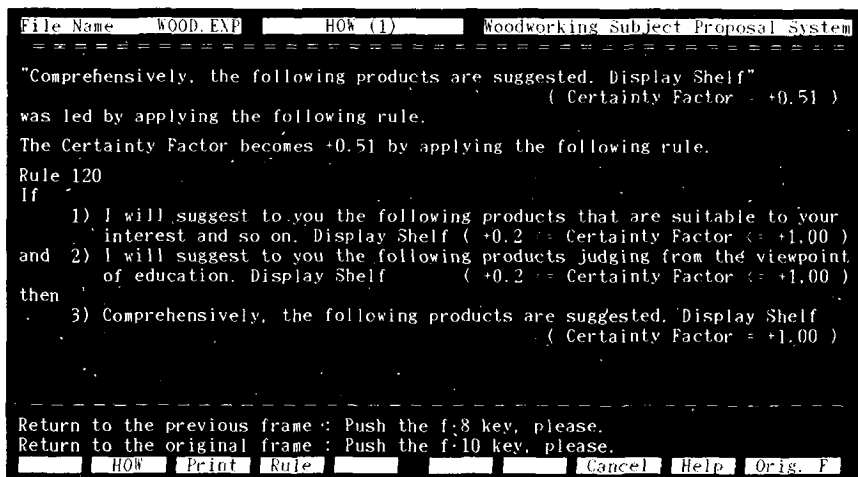


Photo 7

display shelf (see Photo 4) was proposed as a subject by using the HOW function*. According to Photo 7, it is found that rule #120 (meta-rule) was applied. Furthermore, when the user tries to know how the 1st assumption of rule #120 was applied for instance, he/she finds rule #33 (Photo 8) was applied, and as for the 1st assumption of rule #33 for instance, he/she finds rule #2 (Photo 9) was applied. Finally, the system displays that the user's interest, that is the field of art/craftwork, was given by him/her in case of the 2nd assumption in rule #2, and the execution of the HOW function ends. Also, when the user tries to know how the 2nd assumption of rule #120 (see Photo 7) was applied for instance, he/she finds rule #99 (Photo 10) was applied, and similarly, when the user tries to know how the 2nd assumption of rule #99 was applied, he/she finds that 2 rules, rule #72 (Photo 11) and rule #81 (Photo 12) were applied**. Furthermore, as for the assumption of rule #72 (see Photo 11), the user finds that rule #66 (Photo 13) was applied. Finally, the system displays; "It was given by you that you

*Execute by pushing the f.2 key.

**Note that the Certainty Factor is indicated by the negative (minun) sign.


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File Name  WOOD.EXP  HOW (2)  Woodworking Subject Proposal System
=====
"I will suggest to you the following products that are suitable to your interest
and so on. Display Shelf" ( Certainty Factor  +0.51 )
was led by applying the following rule.

The Certainty Factor becomes +0.51 by applying the following rule.
Rule 33
If
  1) The interim conclusion (the relation between the interest and the
      product) Art/Craftwork. ( +0.20 : Certainty Factor  +1.00 )
and 2) The interim conclusion (the relation between your living environment and
      wood product) Others, Home. ( +0.20 : Certainty Factor  +1.00 ) or
  3) The interim conclusion (the relation between your living environment and
      wood product) Others, Lodging. ( +0.20 : Certainty Factor  +1.00 )
then
  4) I will suggest to you the following products that are suitable to your
      interest and so on. Display Shelf ( Certainty Factor  +0.80 )
----- ( continued )
Return to the previous frame : Push the f-8 key, please.
Return to the original frame : Push the f-10 key, please.
HOW  Print  Rule  Pre. F  Next F  Cancel  Help  Orig. F

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Photo 8

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File Name  WOOD.EXP  HOW (3)  Woodworking Subject Proposal System
=====
"The interim conclusion (the relation between the interest and the product) Art/
craftwork." ( Certainty Factor  +0.80 )
was led by the following rule.

The Certainty Factor becomes +0.80 by applying the following rule.
Rule 2
If
  1) The product that you want to produce is concerning your interest.
      ( +0.20 : Certainty Factor  +1.00 )
and 2) The field of your interest is Art/Craftwork.
      ( +0.20 : Certainty Factor  +1.00 )
then
  3) The interim conclusion (the relation between the interest and the
      product) Art/Craftwork. ( Certainty Factor  +0.80 )
-----
Return to the previous frame : Push the f-8 key, please.
Return to the original frame : Push the f-10 key, please.
HOW  Print  Rule  Cancel  Help  Orig. F

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Photo 9

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File Name  WOOD.EXP  HOW (2)  Woodworking Subject Proposal System
=====
"I will suggest to you the following products judging from the viewpoint of
education. Display Shelf" ( Certainty Factor  +0.57 )
was led by applying the following rule.

The Certainty Factor becomes +0.57 by applying the following rule.
Rule 99
If
  1) I want to adopt more than 3 types of joints.
      ( +0.50 : Certainty Factor  +0.90 )
and 2) I do NOT want to use the hollow chisel mortiser.
      ( +0.30 : Certainty Factor  +0.70 )
and 3) I want to use the jig saw.
      ( +0.50 : Certainty Factor  +0.90 )
then
  4) I will suggest to you the following products judging from the viewpoint
      of education. Display Shelf ( Certainty Factor  +0.90 )
-----
Return to the previous frame : Push the f-8 key, please.
Return to the original frame : Push the f-10 key, please.
HOW  Print  Rule  Cancel  Help  Orig. F

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Photo 10

```

File Name  WOOD.EXP      HOW (3)      Woodworking Subject Proposal System

"I want to use the hollow chisel mortiser."      ( Certainty Factor      0.64 )
was led by applying two rules.
I will show you the 1st one.

The Certainty Factor becomes +0.72 by applying the following rule.

Rule 72
If
    1) I want to spend time from 20 hours to 30 hours.
                                   ( +0.50      Certainty Factor      +1.00 )
then
    2) I want to use the hollow chisel mortiser.
                                   ( Certainty Factor      +0.90 )

* : Previous Rule      : Next Rule
Return to the previous frame : Push the f-8 key, please.
Return to the original frame : Push the f-10 key, please.

HOW      Print      Rule      Cancel      Help      Orig. F

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Photo 11

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File Name      WOOD.EXP      How (5)      Woodworking Subject Proposal System

"I want to use the hollow chisel mortiser."      ( Certainty Factor      0.64 )
was led by applying two rules.
I will show you the 2nd one.

The Certainty Factor becomes      0.64 by applying the following rule.

Rule 81
If
    1) I want to use plain, flat cut boards, mainly.
                                   ( -0.50      Certainty Factor      -1.00 )
then
    2) I do NOT want to use the hollow chisel mortiser.
                                   ( Certainty Factor      -0.90 )
    3) I do NOT want to use the wood turning lathe.
                                   ( Certainty Factor      -0.90 )

: Previous Rule.      : Next Rule
Return to the previous frame : Push the f-8 key, please.
Return to the original frame : Push the f-10 key, please.

HOW      Print      Rule      Cancel      Help      Orig. F

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Photo 12

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File Name      WOOD.EXP      How (4)      Woodworking Subject Proposal System

"I want to spend time from 20 hours to 30 hours." ( Certainly Factor  +0.80 )
was led by applying the following rule.

The Certain Factor becomes +0.80 by applying the following rule.

Rule 66
If
    1) I want to spend money from 2000 yen to 4000 yen.
      ( +0.5      Certainly Factor  +1.00 )
then
    2) I want to spend time from 20 hours to 30 hours.
      ( Certainly Factor  +0.80 )

Return to the previous frame : Push the f-8 key, please.
Return to the original frame : Push the f-10 key, please.

      How      Print      Rule      Cancel      Help      Orig. F

```

Photo 13

want to use plain, flat cut boards, mainly." in the case of the assumption of rule #81(see Photo 12), and "It was given by you that the cost for the product is from 2000 yen to 4000 yen per student." in the case of the assumption of rule #66 (see Photo 13), then the execution of the HOW function ends.

Thus the user is able to comprehend how products were proposed as subjects by tracing the progress of the inference under various conditions and also is able to comprehend the changes of the Certainty Factor.

IV Evaluation of the system and Discussion

35 students who are studying or have studied "Practice in Woodworking" made good use of this system and filled out questionnaires on the following scale labels (evaluation items). The evaluation by 5 point scale (evaluation index; -2, -1, 0, 1, 2) ranging from inferior to superior, was adopted (Figure 2).

- ① *The feelings of satisfaction of one's own taste represented by one's interest etc.:* Whether the products (usually, plural) that were suggested as "The conclusion based on your personal motive" are agreeable to one's interest, the practicality of the product and one's life style or not.
- ② *The feelings of the attainment of one's intention based on the viewpoint of education:* Whether knowledge obtained through "Woodworking I" and "Laboratory in Engineering I (a field concerned in Woodworking I)" is reflected in the product or not.
- ③ *The value as a consultation system:* Whether the system is valuable as a consultant or not.
- ④ *The comprehension of the intention of the question (the WHY function):* How well the user is able to comprehend the expert's thought. In other words, how well the user is able to comprehend the points which the expert thinks important.
- ⑤ *The comprehension of the expert's thinking process (the HOW function):* How well the user is able to analyze the difference of the thinking process between the expert and the user by tracing back the process.
- ⑥ *The review of study items:* How well the user is able to review the content that studied in "Woodworking I" and "Laboratory in Engineering I (a field concerned in Woodworking I)" through the explanation about the proposed subject.
- ⑦ *The value as a trainer:* How well the application, the development and the settlement of knowledge regarding Woodworking are able to be expected owing to the user's ability to experience various situations easily by changing the interest variously for example and how well the proposed subjects, the thinking process and so on for each situation are able to be learn.

Figure 2 shows that more than 55% of the students evaluated this system superior (the evaluation index 1 and 2 in the figure) on every evaluation item. This result implies that the expert system plays an important role in computer aided education. In regard to each of 4 items such as "③ the value as a consultaion system", "④ the WHY function", "⑤ the HOW function" and "⑦ the value as a trainer", it should be especially noticed that more

than 70% of the students evaluated this system superior. In addition, the remarkable difference between "the value as a trainer" and another 3 items is observed as follows. As to "the value as a trainer", about 50% of the students showed a highly positive attitude scored 2 and this percentage is above 2 times as much as that of the index 1. In the case of another 3 items, the percentage of the index 2 is less than that of the index 1. From these results, it should be emphasized that "the value as a trainer" is in many ways superior. On the other hand, we must pay attention to the fact that there are students who evaluated the system inferior (the index -1 and -2) on every item, though the percentage is less than 15%. This result suggest that we must recognize the limit in application of the expert system. As a result, it is considered that primarily individualized and high quality education will be expected to introduce the expert system because the instructor is thereby able to spend appropriately more time on individual education owing to the fact that he/she is not needed to guide each students conventionally.

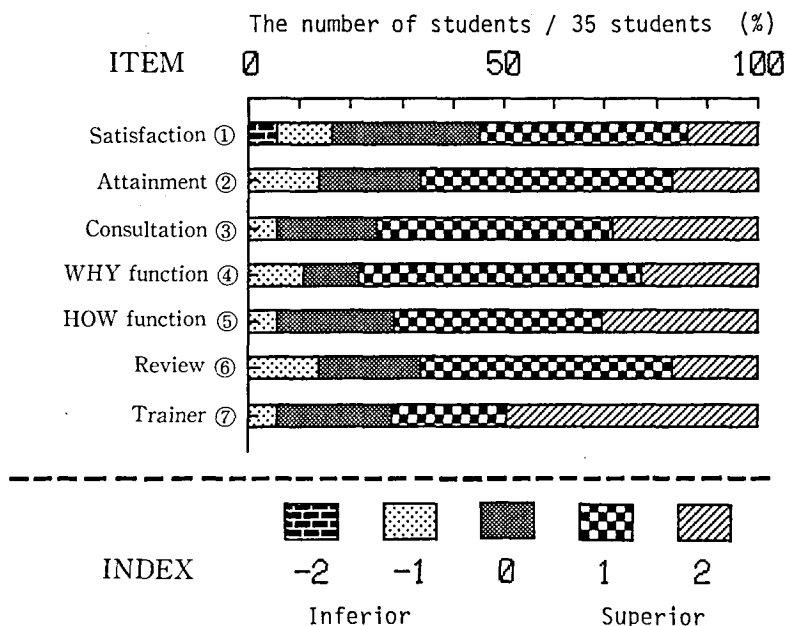


Figure 2 Results of evaluation

V Conclusion

An expert system was constructed by using an expert shell (a tool to construct an expert system) in this paper. The system is able to show the conclusion (the practice subject) with its sketch drawing and prepares the certainty based on the expert's experience in "Practice in Woodworking". Through a conversation with the system, a user is able to ask the intention of the question and is able to learn what kind of rule was applied in the process of inference. As a result, it is admitted that the system is especially valuable as a trainer. Furthermore, it is considered that the utility value as a trainer will be expected similarly in other educational fields such as the adjustment of a gasoline engine (a relation between knocking and a cause,

for example) or the malfunction diagnosis in an electric circuit (a relation between a symptom and a cause) and so on.

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教育用トレーナとしてのエキスパート・システムについて

(橋本孝之・井津元世士郎・小鹿丈夫・寺石 稔・中住 晃)

本研究では、エキスパート・システムがコンピュータ援用学習に於て1つの重要な役割を果たすことを明らかにしている。具体例として、「木材加工学実習」における製作実習課題(製品)を学生が決定する際の支援システム(エキスパート・システム)を取り上げている。このシステムは、専門家(教師)の知識のみならず課題製作者(学生)の個人的な趣味なども十分に反映された推奨課題(結論)を提案でき、かつ製品の構想図なども表示することによって課題の具体的なイメージを把握し易いように開発されている。本システムを7つの項目について評価したところ、十分に高い評価が得られ、とくにトレーナとしての価値が非常に優れていることが明白になった。即ち、システムとの対話を通して、その質問が「なぜ」されたのか、あるいは「如何なるプロセスで」その結論が導き出されたのかを知ることにより、専門家の思考過程の理解や専門家との考え方の相違点の分析、さらに思考過程の理解などに於て必要となる学習事項の復習などが十分に期待できることが示唆された。