

## Chapter 5

### THE WORKING SYSTEM

#### 5.1 INTRODUCTION

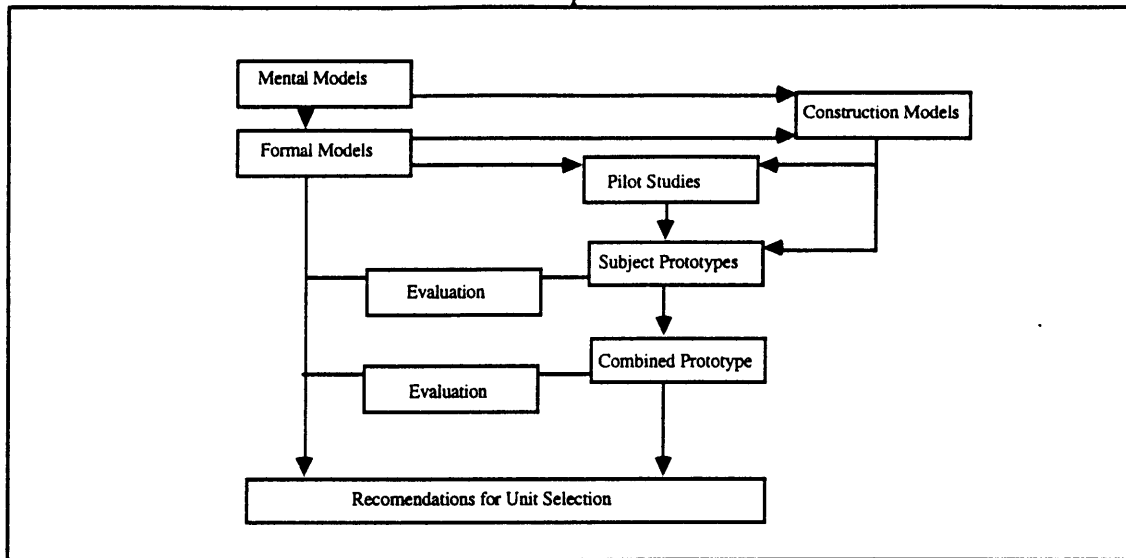
This chapter describes the main features of the computer software program KES II™ (Knowledge Engineering System) which was used to develop expert systems for this research project. It also describes in detail the process of knowledge elicitation and knowledge representation used to model and present the knowledge in the expert system RUS (Recommending Unit Selection).

To develop an effective expert system, it was necessary to construct and evaluate appropriate models. Although these models inevitably reflected some of the human expert's thought processes, they were primarily intended to model the human expert's recommendations. The RUS system was not intended to solve problems by changing curriculum or administrative procedures, but was intended to provide a model of the existing arrangements and possible solutions.

The RUS system was empirically based; that is, the research started with the data that were available — mainly contained in the school's Course Outlines which had been developed and modified over the previous few years. The *Dripstone Course Outlines* (Dripstone 1993) contained descriptive, prescriptive and normative models through a combination of text, tables and flow charts. The expert system was intended to simulate and optimise personal use of the *Dripstone Course Outlines* while also incorporating access to specific individual student data as well as incorporating additional heuristic knowledge which teachers may use when advising students and parents.

The research paradigm illustrated in figure 5.1.1 evolved from the literature reviewed in Chapter Two and was introduced in Chapter Three.

*Figure 5.1.1  
Research implementation model*



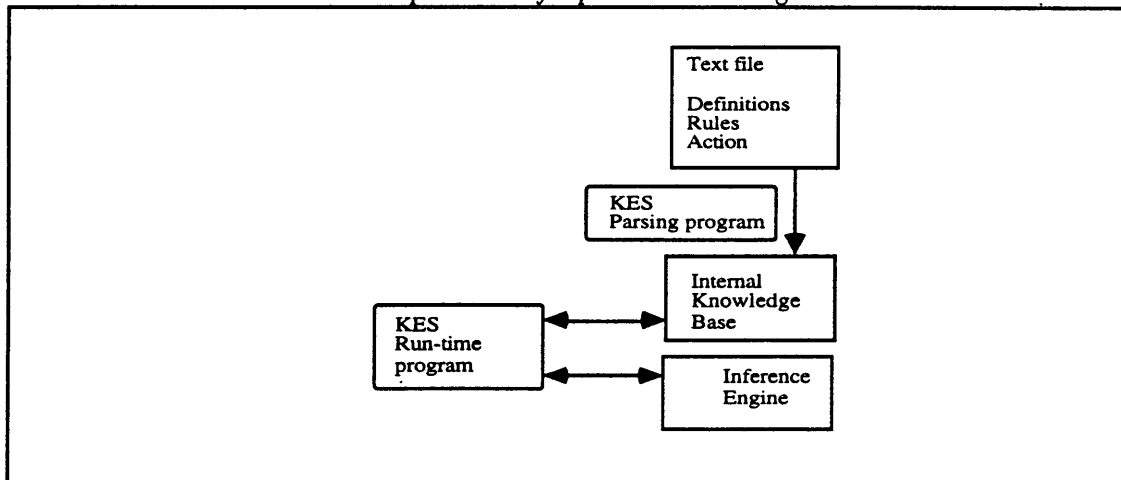
## 5.2 KES II

An interactive session using an expert system developed with KES would typically commence with an introduction message on the screen, followed by a series of selected questions to the user. Users may be asked to respond to a multiple choice question although the program also caters for numeric value, or character string user input. On screen help facilities are available during the session, including the option to seek an explanation of any questions asked. On completion, KES provides a recommendation which users may ask to be justified.

KES provides three separate inference engines to cater for rule based Production System (PS engine), Hypothesise and Test (HT engine), or statistical reasoning (BAYES engine) expert systems. These engines can be run independently or linked together and may share data. All three KES inference engines use a goal directed (backward chaining) approach; the difference between them is the manner in which the knowledge is represented and the information processed. Two of the KES sub systems (PS and HT) can also perform event-driven (forward chaining) inferencing in which it responds to an occurrence rather than pursuing a goal; that is, a value is assigned to an attribute which causes other events to occur. Thus, depending on end-user requirements, a KES expert system may be prepared to perform backward and/or forward chaining.

Each KES knowledge base has three main components: (1) definitions, (2) rules, and (3) action. Demons are an optional component. These components are prepared in a text file using a standard text editor. The KES is then used to convert (parse) the text file into a internal knowledge base, during which the knowledge base is checked for correct syntax. The parsed knowledge base is then accessed by a KES run-time program. Figure 5.2.1 provides a simple model of these elements.

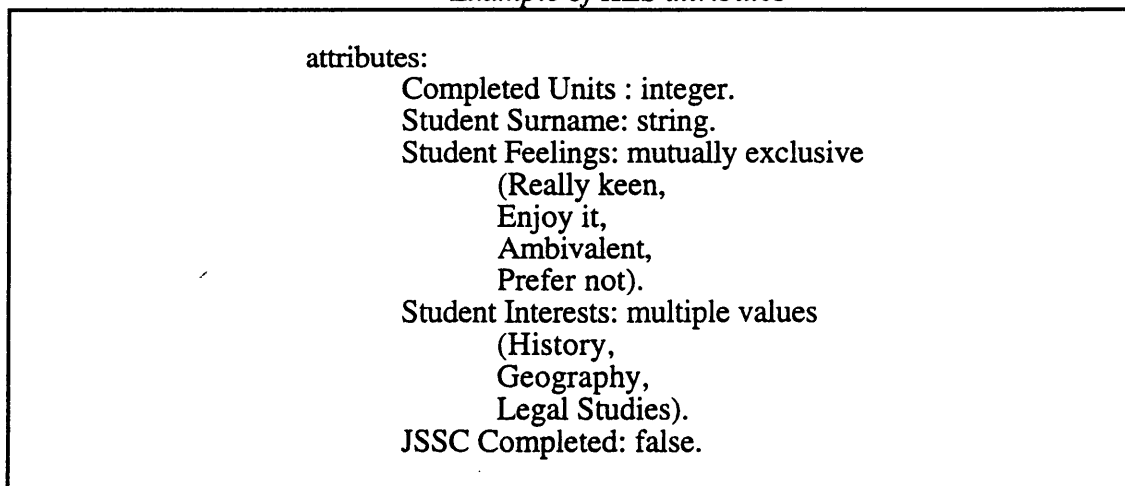
*Figure 5.2.1  
Preparation of a parsed knowledge base*



### 5.2.1 DEFINITIONS

The definitions must include data types and attributes and may include constants, text, patterns, and classes. There are six predefined data types: integers, real numbers, strings, mutually exclusive, multiple values, and true/false. The attributes define the input data to be obtained and the output recommendations; for example,

*Figure 5.2.2  
Example of KES attributes*



There are two kinds of attributes: (1) Input attributes have a value stated in the program, read from other files or an embedded interface, or determined by asking the end user; and (2) Inferred attributes have values attributed by the program either from descriptions or calculations. When seeking a value for an attribute, the program searches internally before examining designated external files or, if still unsuccessful, asking the user. Thus in this project, for example, the student files were directly accessed and historical data such as previous unit achievements did not need to be entered by the user unless the expert system required some information that was not contained on the student's file, such as subject preferences.

### 5.2.2 RULES

The rules are used to infer values for these attributes; for example,

*Figure 5.2.3  
Example of KES rules*

```

Geography Enjoy diagnosis:
  if
    Student Interest = Geography
    and
    Student Feelings = Enjoy it
  then
    Interests = Geography <0.60>
  endif

Geography recommendation:
  if
    Grades <prior geography> satisfactory
    and Core Curriculum is completed
    and interests = Geography or Geology
  then
    Subject recommendation = Extension Geography
  endif

```

KES uses triggers during the inference process to examine the antecedent/s of each rule. The rules are triggered when they might contribute a value for attributes required by the consequent that is being sought. Triggering a rule does not imply that the rule will be fired; that will only occur if the rule's antecedent condition evaluates to true. In this process, KES uses the principle of short-circuit evaluation in determining which rules need to be fired. Thus the order of antecedents within each rule is important because rules cease to be considered when an antecedent does not apply. For example,

*if       the student is in year ten  
          and student is interested in geology  
then     Subject recommendation ABC*

will only seek out the student's interest in geology if the student is in year ten, whereas the following rule would always seek out the student's interest in geology

*if       the student is interested in geology  
          and student is in year ten  
then     Subject recommendation ABC.*

For this reason, in figure 5.2.3, a student's interest in Geography or Geology would only be sought if the other conditions, satisfactory geography grades and core curriculum completed, were first satisfied. To ascertain whether these conditions had been satisfied, the program would search the available data and previous inferences or attempt to trigger other rules before asking the user.

Short-circuit evaluation reduces the work-load of the inference engine by minimising unnecessary data searches, but will only do so with careful rule construction. Further, although all rules are eligible to be triggered and will be re-examined if necessary, they are considered in programmed order and thus it is appropriate to consider their placement in a logical sequence.

### 5.2.3 ACTION

The actions list the commands to be executed; for example,

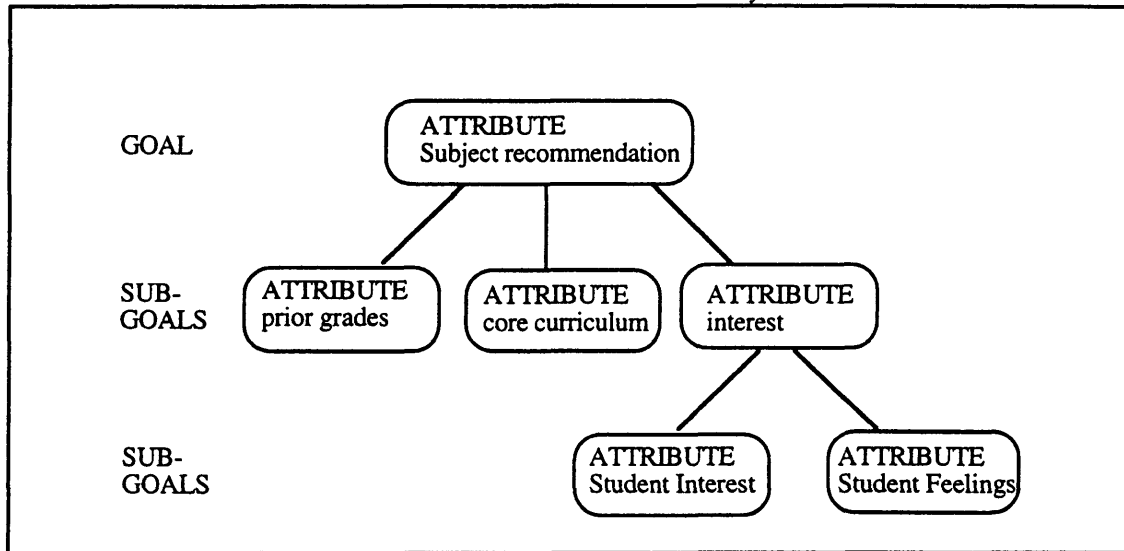
*Figure 5.2.4  
Example of KES action section*

<p>message welcome obtain Subject recommendation justify Subject recommendation message start again</p>
---

The KES rule-based system sequentially executes the commands specified in the actions section. In this example (figure 5.2.4) the welcome screen will be displayed and then the obtain command causes the KES to set an explicit goal of determining the current value for the attribute *Subject recommendation*. The KES first selects the rule which assigns a value to subject recommendations. However, to use this rule it must find values for three attributes and thus has three subgoals. Two of these, prior grades and core curriculum, may be satisfied by an examination of the student records. The

inference engine then sets to obtain the third subgoal for which it then needs to find values for the attributes *Student interest* and *Student feelings*. If there are no rules that can help infer a value for these subgoals, the inference engine concludes that they must be input attributes and asks the user. Once the subgoals are accomplished, the inference engine uses (fires) the rule and infers a value for the attribute *interest* and subsequently fires the rule to infer a value for *Subject recommendation*. This example of attribute hierarchy is illustrated in figure 5.2.5.

Figure 5.2.5  
KES attribute hierarchy



#### 5.2.4 DEMONS

The inference engine uses rules in a backward chaining process to search for conditions that satisfy a goal stipulated in the action component. Rules are active in that they seek out conditions to satisfy their attributes, whereas demons are passive until the attribute is satisfied. This searching by rules may result in other rules being fired to satisfy a sought condition, but in the process of backward chaining rules do not consult demons to obtain values for attributes and thus demons are not a knowledge source for the rules. Demons provide event-driven inferencing by firing as soon as their guard is satisfied by the stipulated internal or external condition. When activated, a demon immediately takes precedence over the other components until its body and any subsequent demons activated have been executed. Demons provide forward chaining as, instead of searching for the conditions to satisfy a goal, they initiate other events. Demons are more powerful than rules as they can, *inter alia*, change the value of attributes including the attribute that triggers their execution. A value assigned to an attribute by a demon is final unless subsequently changed by that or another demon.

Demons may also suspend the execution of a program. The following example helps to illustrate the difference between rules and demons.

<i>Rule</i>	<i>If</i>	<i>Subjects Completed = Extension Geography</i>
	<i>Then</i>	<i>Subject recommendation = No more Geography</i>
	<i>Endif.</i>	
<i>Demon</i>	<i>When</i>	<i>Subjects Completed = Extension Geography</i>
	<i>Then</i>	<i>Subject recommendation = No more Geography</i>
	<i>Endwhen.</i>	

In this example, satisfying the goal to provide the subject recommendation appears very similar. The rules will, however, also seek other attributes to try to make as many subject recommendations as possible. The demon, however, has been satisfied and no other subject recommendations can be made.

### 5.2.5 CERTAINTY FACTORS

The KES has provision for certainty factors (cf) in both the rule-based (PS) and hypothesize-test (HT) sub systems. Rules and attributes have a default value of +1.0 and may range from +1.0 to -1.0 but, unlike some software, rules with multiple certainty factors cannot have total values outside the range +1.0 to -1.0. For example,

<i>Colour = Red</i>	will have a default cf of +1.0,
<i>Colour = Red Green</i>	will result in a default cf of 0.5 for each, and
<i>Colour = Red&lt;0.4&gt; Green</i>	will result in a default cf of <0.6> for green.

Conditions may be imposed requiring a minimum certainty factor before the value of an attribute is accepted; the default is zero, as a negative certainty factor denies truth. Dependent on the attribute type, multiple rules can contribute to the attribute value, in which case the final value is a disjunction of the contributing values so that the attribute certainty factor remains in the +1.0 -1.0 range. Some attribute types (numeric and strings), however, are deemed successful by the first successful rule.

### 5.2.6 INFERENCE ENGINE SELECTION

The selection of one, or more, appropriate inference engines depends on the input characteristics and desired outcome as illustrated in figure 5.2.6. Unisys (1987a, 5-8) recommend using a sub system that reflects the nature of the domain being modelled. If necessary, more than one inference engine can be used. The rule-based (PS) subsystem is recommended where the domain is already or easily converted to

branching logic or if-then rules. The hypothesize and test (HT) subsystem reflects abductive reasoning and is intended for diagnostic problem solving and classification applications. It is only useful when minimal set covering is appropriate; that is, determining the smallest number of causes that explain all the known manifestations of the problem for example, fault diagnosis. This subsystem uses frame-like descriptors. The probability (Bayes) subsystem performs statistical pattern classification based on Bayes' theorem and is recommended for situations where there is a large body of information already expressed as probabilities.

*Figure 5.2.6*  
*KES inference engine selection criteria*  
(Unisys 1987a, 5-14)

Discriminating Requirements	PS	HT	BAYES
Classes, class members, class families	✓		
Multilevel attribute hierarchies	✓	✓	
Automatic search and question pruning	✓	✓	
Outcome is subset selected from set of possible solutions	✓	✓	
Statistical data is available or can be gathered			✓
Inputs are not statistically independent	✓	✓	
Outcomes are not mutually independent	✓	✓	
Outcomes are independent	✓		
Certain outcomes follow directly from certain inputs	✓		
Outcomes should have minimum of solutions		✓	
Only probabilistic relationships are known			✓
Explore alternative path	✓		
Event-driven inferencing is possible	✓	✓	

### 5.2.7 SYSTEM SELECTION OUTCOME

Although the hypothesise and test (HT) inference engine appeared the most interesting, the rule based (PS) system was selected as the appropriate inference engine for the subject selection domain. This decision was confirmed by a small trial application of the HT system to one part of the domain. Whereas the PS inference engine was able to make one or more valid subject recommendations for a variety of reasons, the HT inference engine endeavoured to prioritise the variety of reasons to make a single recommendation.



KES appeared to satisfy the features recommended in Chapter Two. It has a high-level language for expressing procedural knowledge, the language is readable and manageable, people are able to read and understand the rules with little or no training, the rules can be modified or augmented with only modest training, there are facilities for explanation and interface interaction, and it appeared to be compatible with the school administration computer systems already in Northern Territory schools.

### 5.3 KNOWLEDGE ELICITATION

The document *Dripstone High School Course Outlines* (Dripstone 1993) was intended to provide sufficient information to assist students, parents and teachers consider and select appropriate units for the following term within targets set for the end of year ten. Unit pre-requisites were listed in the form a pass in Unit xx. Year Ten certificate requirements were detailed in the introduction and within each subject area chapter. These requirements were mechanical but often complex and there remained an important role for the teaching staff to provide individual counselling to interpret the mechanical procedures in addition to providing professional and often subjective judgements.

Following the preliminary study to select appropriate software, the next task was to develop the expert system to embody the mechanical knowledge contained in the school's publicised formal models. This was done separately for each faculty area using the school's published Course Outlines. A modular approach was adopted for programming considerations, such as operational speed, and to enable separate components to be demonstrated and modified by the subject specialists.

The faculty expert systems were initially evaluated using synthetic data which was created to represent a wide variety of situations. Two different approaches were used for this task. Test data for the Art and Drama faculties was prepared using theoretical options derived from spreadsheet calculations. The spreadsheet calculations were edited to reject unrealistic patterns but retain both normal and unlikely enrolment patterns. These patterns were transferred to create test data files which the expert system could access. Figure 5.3.1 is an extract from the spreadsheet which lists all the correct possible unit combinations which a student could undertake in the Drama faculty (the complete four page spreadsheet is included in Appendix One). For example, a student may have only completed DR110 or DR140 or both. It is also possible for a student to complete DR110 140 220 230 240 and 310 or 320 or 330 or 340.

*Figure 5.3.1*  
*Extract of possible Drama unit combinations*

110							
140							
110	140						
110	140	220	230	240	310		
110	140	220	230	240	320		
110	140	220	230	240	330		
110	140	220	230	240	340		
110	140	210	220	230	240	310	320
110	140	210	220	230	240	310	330
110	140	210	220	230	240	310	340
110	140	210	220	230	240	320	330
110	140	210	220	230	240	320	340
110	140	210	220	230	240	330	340

Following the preparation of spreadsheets for the Art and Drama faculties, it was considered impractical to attempt these for the other faculties. A computer program was written to prepare synthetic samples to test the initial data elicited for these faculties. This program excluded significant sample errors, such as enrolling in units at a given level without having completed any units at the previous level; but did create many samples that were nonsense. A significant number of samples created by this program was used to test the initial faculty expert systems; until it was apparent that most of the 'errors' were from the sample rather than the faculty data or expert system coding.

The test-data evaluation highlighted difficulties that people outside some subject domains may have interpreting the school's publications. In particular, some test-data suggested situations which were overlooked by the current manual system. It was necessary to interview some faculty co-ordinators and other senior staff to resolve these omissions and elicit further knowledge.

An early task for this research project had been to encourage and prepare staff (1) for the role they could undertake and (2) the potential short and long term benefits that could accrue from the project. General discussions with staff were augmented by two memorandums. The first (figure 5.3.2) was intended to provide a general background to the project, the second (figure 5.3.3) was a precursor to individual staff participation in the knowledge elicitation process.

*Figure 5.3.2  
Staff Background Briefing*

**Recommending Unit Selection - RUS  
Staff Background Information**

The start of the Unitised and Vertical Timetabling structure at Dripstone was done at a time when there were relatively few constraints imposed by the Northern Territory Board of Studies. The introduction of minimum time allocations across the curriculum, and other factors, now means that student choices have been reduced to options within subjects plus a very limited number of 'extension' units. The changes have also created a greater need for students, parents and teachers to ensure that correct choices are made; because once made it may be too late to correct within the current time spent at school.

Despite the publication of handbooks and the counselling role intended for subject specialists, it remains a complex process for students, parents, homegroup teachers and others to establish that the correct advice is available/received to help insure correct decisions are made. Printed guide-lines only provide one-way advice. Discussions should help to clarify situations, providing the participants know what questions need to be asked. In any event, a simple misunderstanding or memory lapse may undo these efforts.

Through my research into aspects of artificial intelligence, it would appear feasible to construct an 'Adviser' which is able to keep track of administrative requirements and also to combine the professional knowledge of our experts on staff (you!). Such an Adviser would then be well placed to provide recommendations for students, parents and staff to consider. Naturally such an Adviser would have to be able to explain these recommendations and/or explain why other options were not recommended.

I have commenced the preparation of an Adviser and will be seeking assistance from you our subject experts. The project is not intended to change our timetabling arrangements. Rather, it is intended to document the basis on which you make individual recommendations regarding unit choices in your faculty area. We know that staff within and between faculties often have different perspectives in and outside the subject which they consider. For example, achievement in other units within the faculty, achievement in other faculties, personal interests of the teacher and student, time of the year, and minimum requirements. We know that such advice will be given with varying degrees of confidence. We also know that some advice is based on very subjective and personal grounds which are hard to explain, let alone justify.

I hope that at the end, because of your input, we will have another resource within the school which should be of considerable use to students, parents and staff.

*Figure 5.3.3  
Staff Participation Briefing*

**Recommending Unit Selection - RUS  
Staff Input - Preliminary**

The intention of this part of the exercise is to try and find out what you consider is important when giving advice on unit selection.

You will be asked for your interpretation on how students should select units listed in the current faculty flow-chart. Your response will essentially be a personal one but I do encourage you to try and include all the relevant factors, even if some of them only apply in some situations.

I expect that some of your responses will be quite definitive and that you will have a high degree of confidence in these. For some responses you may feel less confident. This information will be important so please do not exclude any ideas you have just because you cannot justify them or be fully confident they matter.

In some situations you may also need to use subjective terms; for example, if the student 'likes something' then a given unit would be a better choice!

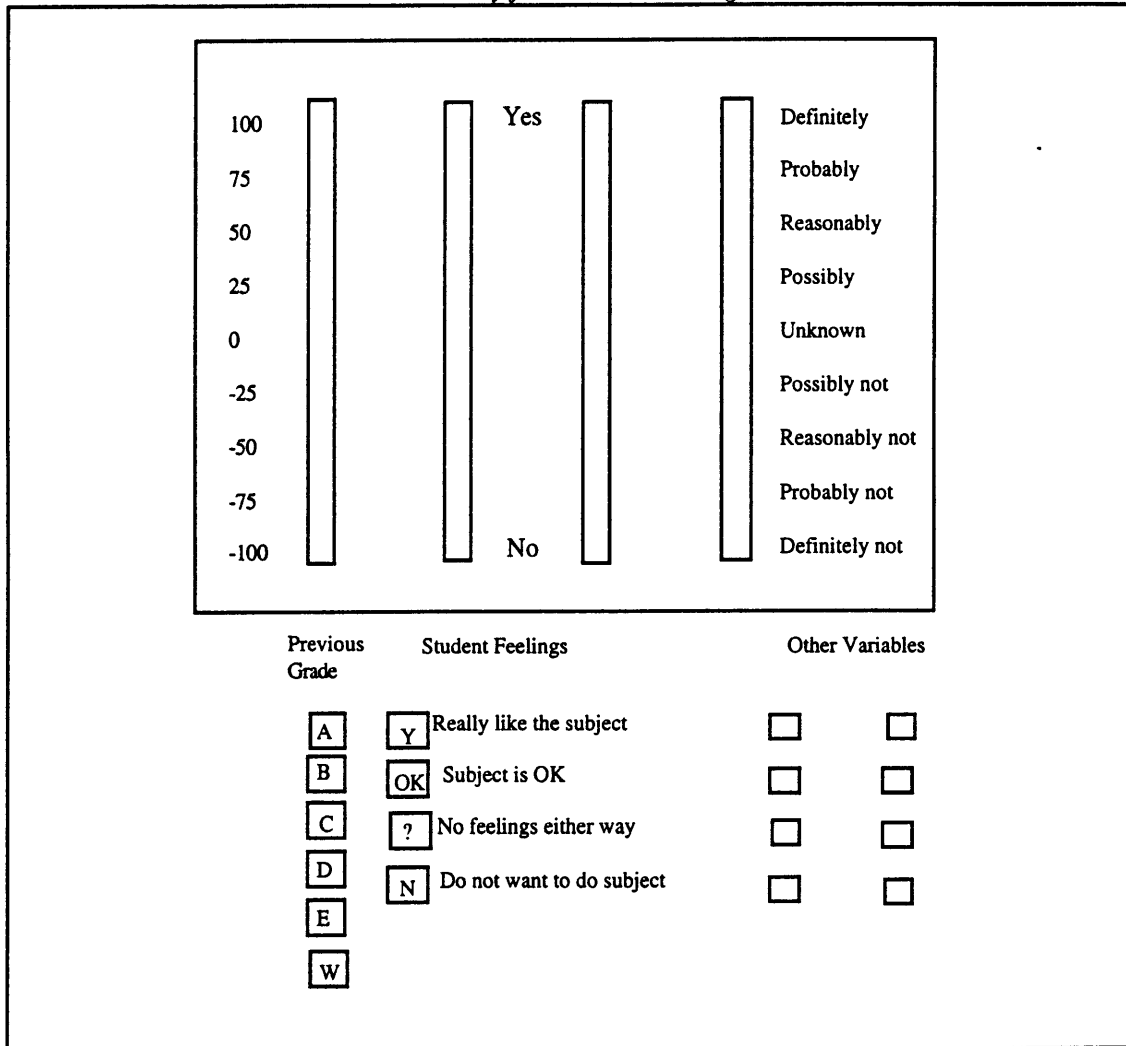
My task is to incorporate all the expert knowledge that you are able to provide, and thus I encourage you share all YOUR ideas no matter what others might think or do and no matter how minor you think they may be.

Your input is for my eyes only. I will attempt to consolidate the responses from different staff and later will be seeking your response to my efforts.

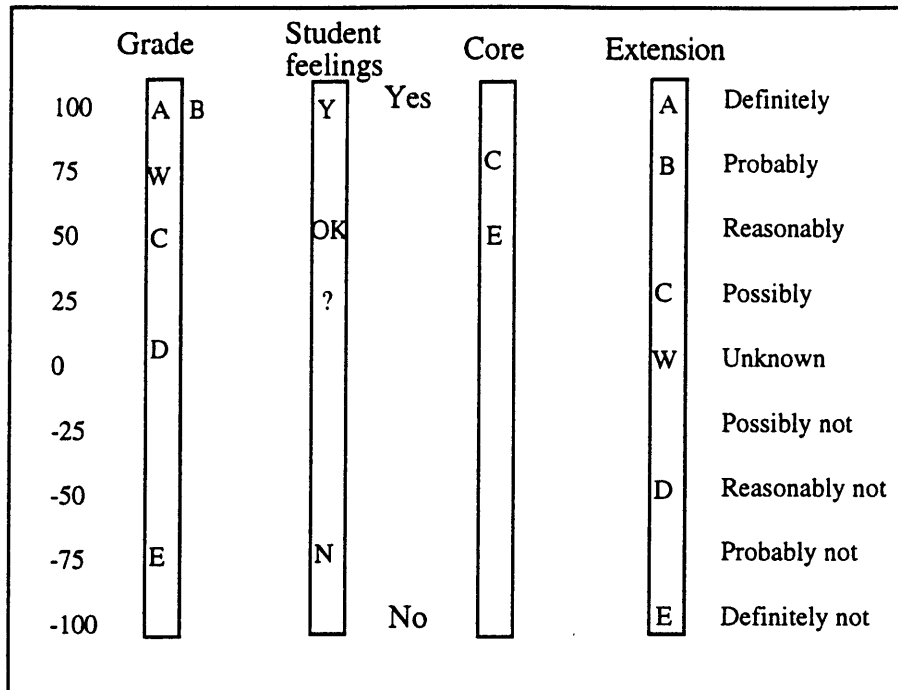
It was also necessary to extend the mechanical knowledge derived from the school's publications by interviewing staff about their use of the structured requirements and to find out other factors which they considered when advising student unit selection. These interviews were also used to find out the importance that staff attributed to these various factors. The use of a Certainty Factor Board (see figures 5.3.4 and 5.3.5) aided the explanation and responses. The board had provision for up to four input variables, using wooden blocks which could be placed in/beside a slot. Three scales were provided in anticipation that some staff would be comfortable using numeric descriptions, while others would prefer a natural language interface. Most staff highlighted student academic performance and student interest as key factors; student behaviour and class compatibility were not strong factors when recommending units, but were more relevant when class groups were allocated; certificate requirements

were rarely mentioned by class teachers and it appeared there was a presumption that such was separate from unit recommendation and the role of either the homegroup teacher or the faculty co-ordinator.

*Figure 5.3.4  
Certainty factor board design*



*Figure 5.3.5  
Certainty factor board example*



The example shown in figure 5.3.5 is one teacher's response to the factors that need to be taken into account when recommending Art units. This teacher indicated that a student with a previous Art grade of A or B definitely should do Art, a student with a W grading (withdrawn from the previous unit as the result of significant absences) probably should do Art, a student with a C grade could reasonably enrol and a D grade would be a low possibility, while a student who only received an E probably should not enrol in more Art units. This teacher also suggested that students who really like Art definitely should enrol, while a student who thinks Art is OK reasonably should enrol and a student who is ambivalent about Art possible should enrol, but a student not wanting to do Art should probably not enrol. A student who has not completed the core (minimum) requirements should enrol — but if there is still time to complete the minimum requirements later then it would not be urgent. A student seeking to enrol in extension units should have previous grades considered. This teacher's response was considered with those of the other faculty members to develop the faculty model in figure 5.4.1.

#### **5.4 KNOWLEDGE REPRESENTATION**

Dripstone High School offers in excess of 200 units, from which students select six each term. There will be many reasons why students desire to study particular units the following term. If no restrictions were placed on the sequence or selection of units which students undertook, then the factorial consequence would be millions of possible unit combinations. The restrictions imposed through unit prerequisites and certification requirements reduces the number of possible combinations to a more manageable, but still significant, figure. However, these restrictions also introduced an obligation to ensure that they were complied with. Although some requirements are relatively easy to understand, such as a pass in unit xx before attempting unit zz, other requirements are a complex combination of possible factors, such as the need to complete some of a range of designated units plus a minimum number of units at each of several levels. A significant element of the project reported in this thesis was the task of representing the breadth and depth of knowledge required to balance these desires and obligations. The research used a number of different models to represent the knowledge available.

It was explained in Chapter Three that the school staff had already participated in a school project for the preparation and publication of the faculty flow charts and descriptors. These publications were used as the base for the research project construction models. A written summary of the pertinent factors for each subject area was developed during the preparation of the subject area expert systems. The pertinent factors included (1) a subject background, (2) the specific elements considered in recommending units, and (3) the general prioritisation of outcomes. These summaries were discussed with the subject co-ordinators. The summary for Art is contained in figures 5.4.1 and 5.4.2, and all the summaries are contained in Appendix One. The various faculty summary models in combination with the faculty flow charts were used to prepare the actual expert systems for each faculty.

*Figure 5.4.1*  
*A faculty summary model*

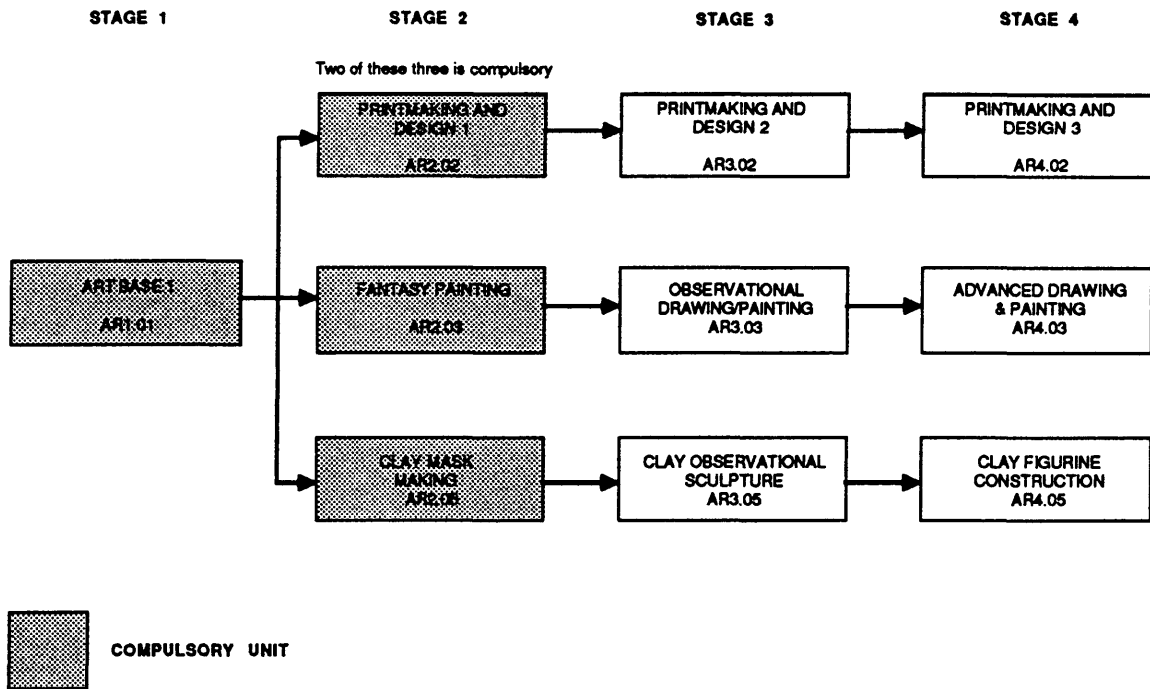
<p><b>ART</b></p> <p><b>Subject background</b> Ten units are available in this subject area. To satisfy the minimum requirements students need to complete an introduction unit and then the first unit in two of the three genre. Two extension units are available in each genre. The compulsory introduction unit has three main topics (Stencil cutting and Airbrushing, Painting and Drawing, and Sculpture). During this unit the teachers make suggestions, based on the students apparent abilities and interests, to individual students on future Art unit selection. The staff reported that students normally have a clear understanding of what art genre they are interested in and successful at; and thus Art unit selection tends to be relatively easy.</p> <p><b>Recommendation antecedents</b></p> <ol style="list-style-type: none"> <li>1. Students are to complete the minimum requirements before proceeding with extension units.</li> <li>2. After completing the introductory unit, students have a choice in sequencing the first unit in each genre.</li> <li>3. The cf &lt;1.00&gt; is applied to the unit recommendations for the three minimum units.</li> <li>4. The following timing recommendations are applied to these units: <table style="margin-left: 40px; border: none;"> <tr> <td style="padding-right: 20px;">first unit</td> <td>"Urgent and Compulsory"</td> </tr> <tr> <td>second unit</td> <td>"Important and Compulsory"</td> </tr> <tr> <td>third unit</td> <td>"Compulsory".</td> </tr> </table> </li> <li>5. Extension units are not recommended unless students express the desire to undertake further art studies.</li> <li>6. The strength &lt;cf&gt; of recommendations for extension units depends on: <table style="margin-left: 40px; border: none;"> <tr> <td colspan="2">stated interest in Art</td> </tr> <tr> <td style="padding-right: 20px;">keen&lt;1.00&gt;, enjoy&lt;1.00&gt;, OK&lt;0.50&gt;, prefer not&lt;0.25&gt;, definitely not&lt;-1.00&gt;</td> <td></td> </tr> <tr> <td colspan="2">grades achieved in prerequisite units</td> </tr> <tr> <td style="padding-right: 20px;">A&lt;1.00&gt;, B&lt;0.75&gt;, W&lt;0.75&gt;, C&lt;0.25&gt;, D&lt;-0.75&gt;, E&lt;-1.00&gt;</td> <td></td> </tr> <tr> <td colspan="2">genre requested &lt;1.00&gt;, genre alternative &lt;0.75&gt;.</td> </tr> </table> </li> <li>7. If requested and the pre-requisites are satisfied, students are allowed to specialise in a genre until both extension units are completed; after which they will be recommended to the appropriate stage in other genres.</li> <li>8. The following timing recommendations are applied to extension units: <table style="margin-left: 40px; border: none;"> <tr> <td style="padding-right: 20px;">fourth to sixth</td> <td>"Extension"</td> </tr> <tr> <td>seventh to tenth</td> <td>"Specialisation".</td> </tr> </table> </li> </ol> <p><b>Solutions</b></p> <p>Minimum requirements = 3 units. Recommend three compulsory units. If acceptable grades in preferred genre then recommend extension units in selected genre else recommend appropriate units in other genre.</p>	first unit	"Urgent and Compulsory"	second unit	"Important and Compulsory"	third unit	"Compulsory".	stated interest in Art		keen<1.00>, enjoy<1.00>, OK<0.50>, prefer not<0.25>, definitely not<-1.00>		grades achieved in prerequisite units		A<1.00>, B<0.75>, W<0.75>, C<0.25>, D<-0.75>, E<-1.00>		genre requested <1.00>, genre alternative <0.75>.		fourth to sixth	"Extension"	seventh to tenth	"Specialisation".
first unit	"Urgent and Compulsory"																			
second unit	"Important and Compulsory"																			
third unit	"Compulsory".																			
stated interest in Art																				
keen<1.00>, enjoy<1.00>, OK<0.50>, prefer not<0.25>, definitely not<-1.00>																				
grades achieved in prerequisite units																				
A<1.00>, B<0.75>, W<0.75>, C<0.25>, D<-0.75>, E<-1.00>																				
genre requested <1.00>, genre alternative <0.75>.																				
fourth to sixth	"Extension"																			
seventh to tenth	"Specialisation".																			

The faculty summary was used to represent the knowledge available in the faculty flow chart, constructed in the faculty decision tree, and elicited during interviews with the human experts.



Figure 5.4.2

## ART FLOWCHART



MINIMUM REQUIREMENTS: 3 COMPULSORY UNITS

The Art decision tree represented the ninety-five pathway options available for students. For example, having completed the compulsory introduction unit AR101 students may enrol in AR202, AR203 or AR205. After completing AR101 and one of these Stage Two units a student needs to enrol in at least one other Stage Two unit and thus will have completed one of the following patterns:

AR101 AR202 AR203

AR101 AR202 AR205

AR101 AR203 AR205.

Thus to complete the minimum requirements for Art involves at least three combinations. In fact there are more than three patterns if one accommodates the order in which units are undertaken, for example AR202 then AR203 or AR203 then AR202, but as the Stage Two units only have AR101 as their common pre-requisite their order is irrelevant and need not be included in the decision tree. On the other hand, pre-requisites and sequential patterns are more significant when tracing the eighty-eight post-compulsory unit patterns and the twenty-eight duplicate patterns are included to avoid apparent omissions when tracing specific branches.

*Figure 5.4.3  
A faculty decision tree*

101					
101	202	101	C	101	C
	C		203		C
	C		C		205
101	202	101	202	101	C
	203		C		203
	C		205		205

Figure 5.4.3 A faculty decision tree (continued)

<b>JSSC</b>							
<b>Extensions</b>							
101	202 203 C	302 C	C	101	202 203 C	302 C	402
				101	202 203 C	302 303	402 C
				101	202 203 C	302 303	402 403
				101	202 203 C	302 303	C C
			duplicate	101	202 203 C	302 303	402 C
			duplicate	101	202 203 C	302 303	402 403
101	202 203 C	C 303	C	101	202 203 C	C 303	C 403
				101	202 203 C	302 303	C 403
			duplicate	101	202 203 C	302 303	402 403
				101	202 203 C	302 303	C C
			duplicate	101	202 203 C	302 303	C 403
			duplicate	101	202 203 C	302 303	402 403

Figure 5.4.3 A faculty decision tree (continued)

101	202 205 C	302 C	C	101	202 205 C	302 C	402
				101	202 205 C	302 305	402 C
			duplicate	101	202 205 C	302 305	402 405
				101	202 205 C	302 305	C C
			duplicate	101	202 205 C	302 305	402 C
			duplicate	101	202 205 C	302 305	402 405
101	202 205 C	C 305	C	101	202 205 C	C 305	405
				101	202 205 C	302 305	C 405
			duplicate	101	202 205 C	302 305	402 405
				101	202 205 C	302 305	C C
			duplicate	101	202 205 C	302 305	C 405
			duplicate	101	202 205 C	302 305	402 405

Figure 5.4.3 A faculty decision tree (continued)

101	203 205 C	303 C	C	101	203 205 C	303 C	403
				101	203 205 C	303 305	403 C
			duplicate	101	203 205 C	303 305	403 405
				101	203 205 C	303 305	C C
			duplicate	101	203 205 C	303 305	403 C
			duplicate	101	203 205 C	303 305	403 405
101	203 205 C	C 305	C	101	203 205 C	C 305	405
				101	203 205 C	303 305	C 405
			duplicate	101	203 205 C	303 305	403 405
				101	203 205 C	303 305	C C
			duplicate	101	203 205 C	303 305	C 405
			duplicate	101	203 205 C	303 305	403 405

*Figure 5.4.3 A faculty decision tree (continued)*

101	202 203 205	302 C C	C	101	202 203 205	302 C C	402
				101	202 203 205	302 303 C	402 C
				101	202 203 205	302 303 C	402 403
				101	202 203 205	302 303 305	402 403 C
				101	202 203 205	302 C 305	402 C
				101	202 203 205	302 C 305	402 405
				101	202 203 205	302 303 305	402 C 405
				101	202 203 205	302 303 305	402 403 405
				101	202 203 205	302 303 C	C C
				101	202 203 205	302 C 305	C C
				101	202 203 205	302 303 305	C C C
				101	202 203 205	302 303 305	402 C C
			duplicate	101	202 203 205	302 303 305	402 403 C
			duplicate	101	202 203 205	302 303 305	402 C 405
			duplicate	101	202 203 205	302 303 305	402 403 405

Figure 5.4.3 A faculty decision tree (continued)

101	202 203 205	C 303 C	C	101	202 203 205	C 303 C	403
				101	202 203 205	302 303 C	C 403
				101	202 203 205	302 303 C	402 403
				101	202 203 205	302 303 305	402 403 C
				101	202 203 205	C 303 305	403 C
				101	202 203 205	C 303 305	403 405
				101	202 203 205	302 303 305	C 403 405
			duplicate	101	202 203 205	302 303 305	402 403 405
				101	202 203 205	202 303 C	C C
				101	202 203 205	C 303 305	C C
				101	202 203 205	302 303 305	C C C
				101	202 203 205	302 303 305	C 403 C
			duplicate	101	202 203 205	302 303 305	402 403 C
			duplicate	101	202 203 205	302 303 305	C 403 405
			duplicate	101	202 203 205	302 303 305	402 403 405

*Figure 5.4.3 A faculty decision tree (continued)*

101	202	C		101	202	C	
	203	C			203	C	
	205	305	C		205	305	405
				101	202	302	C
					203	C	
					205	305	405
				101	202	302	402
					203	C	
					205	305	405
				101	202	302	402
					203	303	C
					205	305	405
				101	202	C	
					203	303	C
					205	305	405
				101	202	C	
					203	303	403
					205	305	405
				101	202	303	C
					203	303	403
					205	305	405
			duplicate	101	202	302	402
					203	303	403
					205	305	405
				101	202	302	C
					203	C	
					205	305	C
				101	202	C	
					203	303	C
					205	305	C
				101	202	302	C
					203	303	C
					205	305	C
				101	202	302	C
					203	303	C
					205	305	405
			duplicate	101	202	302	402
					203	303	C
					205	305	405
			duplicate	101	202	302	C
					203	303	403
					205	305	405
			duplicate	101	202	302	C
					203	303	403
					205	305	405



One of the problems noted in Chapter Two is that of keeping track of knowledge to ensure that redundant and contradictory details do not impinge on the knowledge base. One strategy, advocated by Francioni and Kandel, is the use of decision tables. This concept was attempted in several formats. A decision tree to trace possible Art unit is demonstrated in figure 5.4.3. Figures 5.4.4 and 5.4.5 demonstrate two other formats used to help ensure that appropriate factors were included in the rules and also to assist debugging contradictory recommendations.

*Figure 5.4.4  
Association between prior grades and Stage One English levels*

Units	completed	Grades for Level 1 entry	Grades for Level 2 entry	Grades for Level 3 entry
Compulsory	EN101	A or B and A or B	Minimum C or C	D or E or D or E
	EN102			
Suitable for all	EN103	A	B C	D E
	EN104	A	B C	D E
	EN105	A	B C	D E
Level One	EN111	A B C	C D E	
	EN112	A B C	C D E	
Level Two	EN121	A	B C	D E
	EN122	A	B C	D E
	EN123	A	B C	D E
Level Three	EN131			A B C D E
	EN132			A B C D E
	EN133			A B C D E
	EN134			A B C D E
	EN135			A B C D E

Figure 5.4.4 summarises entry requirements for the Stage One English levels. For example, a student achieving an A or B in both of the compulsory units could apply for a Level One unit EN111 or EN112 and need only achieve at least a C in that unit to enrol in the other Level One unit. Another student achieving a minimum of C in either of the compulsory units would only be entitled to enrol in EN 103-104-105 or EN 121-122-123, but if achieved an A in that unit would then be allowed to enrol in a Level One unit.

*Figure 5.4.5  
Technical Studies pre-requisites decision table*

		Following units												
		210	211	220	221	222	230	240	310	311	320	321	330	340
Prior units														
110		Y	Y	Y		Y	Y	Y						
130		Y	Y	Y		Y	Y	Y						
210									Y					
211										Y				
220					Y									
221											Y			
222														
230													Y	
240														Y
320												Y		

Figure 5.4.5 illustrates the prerequisite units which need to be completed prior to enrolling in following units. For example, a student having completed 110 or 130 may enrol in 210-211-220-222-230-240 but not 221 for which 220 is a prerequisite.

It was decided to use a rule base as the primary system for representing the knowledge elicited in the selected domain. A number of factors contributed to this decision: (1) the selected software offered alternatives but recommended (figure 5.2.5) rules for the selected task, (2) the rule syntax is relatively easy for other people to read and understand, especially because rules can be grouped in convenient modules, (3) more than one rule may contribute to recommendations, and (4) altering and adding rules to the knowledge base is not a complicated process.

In preparing the expert system, it was also considered important to accommodate several warnings noted in Chapter Two. Because end-users can request explanations for questions and recommendations, the mnemonics and other coding were kept user friendly where possible. To further assist the user interface, rule combinations were minimised. A consistent approach was used in each subject knowledge base so that end-users could follow a standard input/question routine. In addition to assisting end-users in this manner, understanding of the logic structure by the teaching staff was also considered to be important. Thus algebraic algorithms were avoided even though they would have reduced the coding required. These features were also intended to make it easier for future modifications of the expert system. The cost of these benefits was additional coding and slower operating speed. Figure 5.4.6 is an extract from the Art faculty expert system.

*Figure 5.4.6  
Extract from Art faculty expert system*

```

AR32 Diagnosis
  If this unit has not already been attempted
  and the student is interested in this theme
  and the student's results in the prerequisite unit are satisfactory
  then recommend unit
    if      Done Units not include AR302
           and INTERESTS = Printmaking Design
           and GRADES:AR202>WeightedResults = Satisfactory
    then    RECOMMEND = AR302
    endif

AR32_22 Diagnosis
  Situation when the student is interested in this theme
  but the results in prerequisite unit were unsatisfactory
  if      Done Units not include AR302
           and INTERESTS = Printmaking Design
           and GRADES:AR202>WeightedResults = Unsatisfactory
  then    RECOMMEND = AR202
           reassert note    "You wanted to do more Printmaking design"
                           "but your grade in AR202 was unsatisfactory."
                           "You may repeat this unit"
                           "or select another Art topic."
  endif

```

## 5.5 A FACULTY EXPERT SYSTEM

The outcome of the various processes involved in knowledge elicitation and knowledge representation is demonstrated in figure 5.5.1 — the expert system developed for the Art faculty. Coding for the other faculty expert systems is contained in Appendix Two.

*Figure 5.5.1  
Art faculty expert system*

\NEXT-ART

constants:

BANNER:

"\*\*\*\*\*",  
"

HOLD:

" Please press c to continue".

%

types:

units:mlt

(AR101, AR202, AR302, AR402, AR203, AR303, AR403, AR205, AR305, AR405,  
ARBF, ARPA, PAINT, ARPR, PRINT, No Art, No Multilevel Art, No\_AR).

%

attributes:

StudSName:str [default: " "].

StudFName:str [default: " "].

StudYear:int.

CurrTerm:int.

NOTES1:str.

NOTES2:str.

NOTES3:str.

NOTES4:str.

TIMING:str.

NotePrint:truth.

NoteDraw:truth.

NoteClay:truth.

DoneUnits:units.

MultiUnits:units.

RECOMMEND:units.

ARTjssc:int [default:0].

ARTcmplt:int [default: 0].

*Figure 5.5.1*  
*Art faculty expert system (continued)*

```

Initial Interests:sgl
(Printmaking Design
    {question:" Printmaking and Design"}
    {explain: "These units are taken by Ms Bailey."},
Drawing Painting
    {question:" Drawing and Painting"}
    {explain: "These units are taken by Mr Tymukas."},
Clay
    {question:" Sculpture and Clay"}
    {explain: "These units are taken by Mr Batten."})
{question: "Which of these Art groups would you prefer next term?"," " }
{explain: "Our recommendations take in acccount your preferences as well as your
grades in the pre-requisite units."}.

INTERESTS:sgl
(Printmaking Design, Drawing Painting, Clay).

FEELINGS:sgl
(Really keen, Enjoy it, Its okay, Prefer not, Definitely not)
{question: "What are you feelings towards doing Art next term?"," " }
{explain: "We only recommend Art extension units to those students who wish to study
more Art!"}.

STAGE:mlt
(Stage one, Stage two, Stage three, Stage four).

INFO:sgl
(Justify
    {question: "Explain the recommendation."},
Again
    {question: "Enter new information about your preferences."},
Continue
    {question: "Continue with the next subject area."})
{question: "What would you like to do now?"," "}.
%
classes:

GRADES:
attributes:
RESULTS:sgl (A, B, C, D, E, W, N).
WeightedResults:sgl (Satisfactory, Unsatisfactory).
%
endclass.
%
rules:
Setup:
    if true
    then  NOTES1 = " ".
        NOTES2 = " ".
        NOTES3 = " ".
        NOTES4 = " ".
        TIMING = " ".
    endif.

```

*Figure 5.5.1*  
*Art faculty expert system (continued)*

```

\ *****
\      Stage One

Stage1 diagnosis:
  if      DoneUnits # AR101
  then    RECOMMEND = AR101.
          STAGE = Stage one.
  endif.

\ *****
\      Stage Two

Stage2 diagnosis:
  if      DoneUnits = AR101
  then    STAGE = Stage two.
  endif.

AR2 triple diagnosis:
\ if no Stage two units then recommend all three compulsory units.
  if
  STAGE = Stage two
  and DoneUnits # AR202 | AR203 | AR205
  then
  RECOMMEND = AR202 & AR203 & AR205.
  endif.

AR22 double diagnosis:
\ if one Stage two unit then recommend the other two compulsory units.
  if
  STAGE = Stage two
  and DoneUnits = AR202 | PRINT
  and DoneUnits # AR203 | PAINT | ARPA
  and DoneUnits # AR205 | ARBF
  then
  RECOMMEND = AR203 & AR205.
  endif.

AR23 double diagnosis:
\ if one Stage two unit then recommend the other two compulsory units.
  if
  STAGE = Stage two
  and DoneUnits = AR203 | PAINT | ARPA
  and DoneUnits # AR202 | PRINT
  and DoneUnits # AR205 | ARBF
  then
  RECOMMEND = AR202 & AR205.
  endif.

AR25 double diagnosis:
\ if one Stage two unit then recommend the other two compulsory units.
  if
  STAGE = Stage two
  and DoneUnits = AR205 | ARBF
  and DoneUnits # AR202 | PRINT
  and DoneUnits # AR203 | PAINT | ARPA
  then
  RECOMMEND = AR202 & AR203.
  endif.

```

*Figure 5.5.1*  
*Art faculty expert system (continued)*

```

AR22 single diagnosis:
\ if two Stage two units then recommend the remaining compulsory unit.
  if
    STAGE = Stage two
    and DoneUnits = AR203 | PAINT | ARPA
    and DoneUnits = AR205 | ARBF
  then
    RECOMMEND = AR202.
  endif.

AR23 single diagnosis:
\ if two Stage two units then recommend the remaining compulsory unit.
  if
    STAGE = Stage two
    and DoneUnits = AR202 | PRINT
    and DoneUnits = AR205 | ARBF
  then
    RECOMMEND = AR203.
  endif.

AR25 single diagnosis:
\ if two Stage two units then recommend the remaining compulsory unit.
  if
    STAGE = Stage two
    and DoneUnits = AR202 | PRINT
    and DoneUnits = AR203 | PAINT | ARPA
  then
    RECOMMEND = AR205.
  endif.

\ *****
\ Student feelings towards and interests in non-compulsory units

Art_Prefer_Not response:
  if
    STAGE = Stage three
    and FEELINGS = Prefer not
  then
    RECOMMEND = No_AR <0.50>.
  endif.

Art_Definitely_Not response:
  if
    STAGE = Stage three
    and FEELINGS = Definitely not
  then
    RECOMMEND = No_AR <1.00>.
  endif.

Print_keen response:
  if
    STAGE = Stage three
    and FEELINGS = Really keen
    and Initial Interests = Printmaking Design
  then
    INTERESTS = Printmaking Design <1.00>.
  endif.

```

*Figure 5.5.1*  
*Art faculty expert system (continued)*

```

Print_Enjoy response:
  if
    STAGE = Stage three
    and FEELINGS = Enjoy it
    and Initial Interests = Printmaking Design
  then
    INTERESTS = Printmaking Design <0.75>.
  endif.

Print_OK response:
  if
    STAGE = Stage three
    and FEELINGS = Its okay
    and Initial Interests = Printmaking Design
  then
    INTERESTS = Printmaking Design <0.30>.
  endif.

Draw_keen response:
  if
    STAGE = Stage three
    and FEELINGS = Really keen
    and Initial Interests = Drawing Painting
  then
    INTERESTS = Drawing Painting <1.00>.
  endif.

Draw_Enjoy response:
  if
    STAGE = Stage three
    and FEELINGS = Enjoy it
    and Initial Interests = Drawing Painting
  then
    INTERESTS = Drawing Painting <0.75>.
  endif.

Draw_OK response:
  if
    STAGE = Stage three
    and FEELINGS = Its okay
    and Initial Interests = Drawing Painting
  then
    INTERESTS = Drawing Painting <0.30>.
  endif.

Clay_keen response:
  if
    STAGE = Stage three
    and FEELINGS = Really keen
    and Initial Interests = Clay
  then INTERESTS = Clay <1.00>.
  endif.

Clay_Enjoy response:
  if
    STAGE = Stage three
    and FEELINGS = Enjoy it
    and Initial Interests = Clay
  then INTERESTS = Clay <0.75>.
  endif.

```



*Figure 5.5.1*  
*Art faculty expert system (continued)*

Clay\_OK response:

```

if
  STAGE = Stage three
  and FEELINGS = Its okay
  and Initial Interests = Clay
then
  INTERESTS = Clay <0.30>.
endif.

```

\ \*\*\*\*\*

\ Stage Three

AR32 diagnosis:

```

\ if this unit has not already been attempted
\ and student is interested in this theme
\ and the student's results in the previous unit are satisfactory
\ then recommend unit
\ but record level of interest in Art and previous grades.
  if
\   STAGE = Stage three
   DoneUnits # AR302
   and INTERESTS = Printmaking Design
   and GRADES:AR202>WeightedResults = Satisfactory
  then
    RECOMMEND = AR302.
  endif.

```

AR32m diagnosis:

```

\ if this unit has not already been attempted
\ and student is interested in this theme
\ and the student's results has done the multilevel unit Print
\ then recommend unit
  if
\   STAGE = Stage three
   DoneUnits # AR302
   and INTERESTS = Printmaking Design
   and DoneUnits = PRINT | ARPR
  then
    RECOMMEND = AR302.
  endif.

```

AR32x diagnosis:

```

\ if this unit has not already been attempted
\ and student is interested in this theme
\ and the student has completed a Stage Four unit
\ then recommend unit
  if
\   STAGE = Stage three
   DoneUnits # AR302
   and INTERESTS = Printmaking Design
   and DoneUnits = AR403 | AR405
  then
    RECOMMEND = AR302.
  endif.

```

*Figure 5.5.1*  
*Art faculty expert system (continued)*

AR32\_22 diagnosis:

```
\ Situation when the previous Stage is completed
\ and student is interested in this theme
\ but the results in unit before were unsatisfactory.
  if
\   STAGE = Stage three
   DoneUnits # AR302
   and INTERESTS = Printmaking Design
   and GRADES:AR202>WeightedResults = Unsatisfactory
   then
   RECOMMEND = AR202.
   reassert NOTES1 = "*** You wanted to do more Printmaking Design".
   reassert NOTES2 = " but your grade in AR202 was unsatisfactory".
   reassert NOTES3 = " You may repeat this unit".
   reassert NOTES4 = " or select a different Art topic. ***".
   endif.
```

AR33 diagnosis:

```
\ if this unit has not already been attempted
\ and student is interested in this theme
\ and the student's results in the previous unit are satisfactory
\ then recommend unit
\ but record level of interest in Art and previous grades.
  if
\   STAGE = Stage three
   DoneUnits # AR303
   and INTERESTS = Drawing Painting
   and GRADES:AR203>WeightedResults = Satisfactory
   then
   RECOMMEND = AR303.
   endif.
```

AR33m diagnosis:

```
\ if this unit has not already been attempted
\ and student is interested in this theme
\ and the student's has done the multilevel unit Paint
\ then recommend unit
\ but record level of interest in Art and previous grades.
  if
\   STAGE = Stage three
   DoneUnits # AR303
   and INTERESTS = Drawing Painting
   and DoneUnits = PAINT | ARPA
   then
   RECOMMEND = AR303.
   endif.
```

*Figure 5.5.1*  
*Art faculty expert system (continued)*

AR33x diagnosis:

```
\ if this unit has not already been attempted
\ and student is interested in this theme
\ and the student has completed a Stage Four unit
\ then recommend unit
  if
\   STAGE = Stage three
   DoneUnits # AR303
   and INTERESTS = Drawing Painting
   and DoneUnits = AR402 | AR405
   then
   RECOMMEND = AR303.
   endif.
```

AR33\_23 diagnosis:

```
\ Situation when the previous Stage is completed
\ and student is interested in this theme
\ but the results in unit before were unsatisfactory.
  if
\   STAGE = Stage three
   DoneUnits # AR303
   and INTERESTS = Drawing Painting
   and GRADES:AR203>WeightedResults = Unsatisfactory
   then
   RECOMMEND = AR203.
   reassert NOTES1 = "*** You wanted to do more Drawing and Painting".
   reassert NOTES2 = " but your grade in AR203 was unsatisfactory".
   reassert NOTES3 = " You may repeat this unit".
   reassert NOTES4 = " or select a different Art topic. ***".
   endif.
```

AR35 diagnosis:

```
\ if this unit has not already been attempted
\ and student is interested in this theme
\ and the student's results in the previous unit are satisfactory
\ then recommend unit
\ but record level of interest in Art and previous grades.
  if
\   STAGE = Stage three
   DoneUnits # AR305
   and INTERESTS = Clay
   and GRADES:AR205>WeightedResults = Satisfactory
   then
   RECOMMEND = AR305.
   endif.
```

*Figure 5.5.1*  
*Art faculty expert system (continued)*

AR35m diagnosis:

```
\ if this unit has not already been attempted
\ and student is interested in this theme
\ and the student's has done the multilevel unit Bougainvillea Parade
\ then recommend unit
  if
\   STAGE = Stage three
    DoneUnits # AR305
    and INTERESTS = Clay
    and DoneUnits = ARBF
  then
    RECOMMEND = AR305.
  endif.
```

AR35x diagnosis:

```
\ if this unit has not already been attempted
\ and student is interested in this theme
\ and the student has completed a Stage Four unit
\ then recommend unit
  if
\   STAGE = Stage three
    DoneUnits # AR305
    and INTERESTS = Clay
    and DoneUnits = AR402 | AR403
  then
    RECOMMEND = AR305.
  endif.
```

AR35\_25 diagnosis:

```
\ Situation when the previous Stage is completed
\ and student is interested in this theme
\ but the results in unit before were unsatisfactory.
  if
\   STAGE = Stage three
    DoneUnits # AR305
    and INTERESTS = Clay
    and GRADES:AR205>WeightedResults = Unsatisfactory
  then
    RECOMMEND = AR205.
    reassert NOTES1 = "*** You wanted to do more Clay".
    reassert NOTES2 = " but your grade in AR205 was unsatisfactory".
    reassert NOTES3 = " You may repeat this unit".
    reassert NOTES4 = " or select a different Art topic. ***".
  endif.
```

```
\ *****
```

*Figure 5.5.1*  
*Art faculty expert system (continued)*

```

\      Stage Four

AR42 diagnosis:
\ if this unit has not already been attempted
\ and student is interested in this theme
\ and the student's results in the previous unit are satisfactory
\ then recommend unit
\ but record level of interest in Art and previous grades.
    if
    INTERESTS = Printmaking Design
    and GRADES:AR302>WeightedResults = Satisfactory
    and DoneUnits # AR402
    then
    RECOMMEND = AR402.
    endif.

AR42_32 diagnosis:
\ Situation when the previous Stage is completed
\ and student is interested in this theme
\ but the results in unit before were unsatisfactory.
    if
    INTERESTS = Printmaking Design
    and GRADES:AR302>WeightedResults = Unsatisfactory
    and DoneUnits # AR402
    then
    RECOMMEND = AR302.
    reassert NOTES1 = "*** You wanted to do more Printmaking Design".
    reassert NOTES2 = " but your grade in AR302 was unsatisfactory".
    reassert NOTES3 = " You may repeat this unit".
    reassert NOTES4 = " or select a different Art topic. ***".
    endif.

AR42_33 diagnosis:
\ if all units in this theme have already been attempted
\ but other units are available in a different theme
\ and the student's results allow entry to those units
\ then recommend alternative unit
\ but record level of interest in Art and previous grades
\ and give explanation to user.
    if
    DoneUnits = AR302 & AR402
    and INTERESTS = Printmaking Design
    and DoneUnits # AR303
\      and GRADES:AR203>WeightedResults = Satisfactory
    then
    RECOMMEND = AR303 <0.75>.
    NotePrint = true.
    endif.

```

*Figure 5.5.1*  
*Art faculty expert system (continued)*

AR42\_35 diagnosis:

```
\ if all units in this theme have already been attempted
\ but other units are available in a different theme
\ and the student's results allow entry to those units
\ then recommend alternative unit
\ but record level of interest in Art and previous grades
\ and give explanation to user.
    if
        DoneUnits = AR302 & AR402
        and INTERESTS = Printmaking Design
        and DoneUnits # AR305
\ and GRADES:AR205>WeightedResults = Satisfactory
    then
        RECOMMEND = AR305 <0.75>.
        NotePrint = true.
    endif.
```

AR43 diagnosis:

```
\ if this unit has not already been attempted
\ and student is interested in this theme
\ and the student's results in the previous unit are satisfactory
\ then recommend unit
\ but record level of interest in Art and previous grades.
    if
        INTERESTS = Drawing Painting
        and GRADES:AR303>WeightedResults = Satisfactory
        and DoneUnits # AR403
    then
        RECOMMEND = AR403.
    endif.
```

AR43\_33 diagnosis:

```
\ Situation when the previous Stage is completed
\ and student is interested in this theme
\ but the results in unit before were unsatisfactory.
    if
        INTERESTS = Drawing Painting
        and GRADES:AR303>WeightedResults = Unsatisfactory
        and DoneUnits # AR403
    then
        RECOMMEND = AR303.
        reassert NOTES1 = "*** You wanted to do more Drawing painting".
        reassert NOTES2 = " but your grade in AR303 was unsatisfactory".
        reassert NOTES3 = " You may repeat this unit".
        reassert NOTES4 = " or select a different Art topic. ***".
    endif.
```

*Figure 5.5.1*  
*Art faculty expert system (continued)*

```

AR43_32 diagnosis:
\ if all units in this theme have already been attempted
\ but other units are available in a different theme
\ and the student's results allow entry to those units
\ then recommend alternative unit
\ but record level of interest in Art and previous grades
\ and give explanation to user.
    if
        DoneUnits = AR303 & AR403
        and INTERESTS = Drawing Painting
        and DoneUnits # AR302
\ and GRADES:AR202>WeightedResults = Satisfactory
    then
        RECOMMEND = AR302 <0.75>.
        NoteDraw = true.
    endif.

AR43_35 diagnosis:
\ if all units in this theme have already been attempted
\ but other units are available in a different theme
\ and the student's results allow entry to those units
\ then recommend alternative unit
\ but record level of interest in Art and previous grades
\ and give explanation to user.
    if
        DoneUnits = AR303 & AR403
        and INTERESTS = Drawing Painting
        and DoneUnits # AR305
\ and GRADES:AR205>WeightedResults = Satisfactory
    then
        RECOMMEND = AR305 <0.75>.
        NoteDraw = true.
    endif.

AR45 diagnosis:
\ if this unit has not already been attempted
\ and student is interested in this theme
\ and the student's results in the previous unit are satisfactory
\ then recommend unit
\ but record level of interest in Art and previous grades.
    if
        INTERESTS = Clay
        and GRADES:AR305>WeightedResults = Satisfactory
        and DoneUnits # AR405
    then
        RECOMMEND = AR405.
    endif.

```

*Figure 5.5.1*  
*Art faculty expert system (continued)*

AR45\_35 diagnosis:

```
\ Situation when the previous Stage is completed
\ and student is interested in this theme
\ but the results in unit before were unsatisfactory.
  if
    INTERESTS = Clay
    and GRADES:AR305>WeightedResults = Unsatisfactory
    and DoneUnits # AR405
  then
    RECOMMEND = AR305.
    reassert NOTES1 = "*** You wanted to do more Clay".
    reassert NOTES2 = " but your grade in AR305 was unsatisfactory".
    reassert NOTES3 = " You may repeat this unit".
    reassert NOTES4 = " or select a different Art topic. ***".
  endif.
```

AR45\_32 diagnosis:

```
\ if all units in this theme have already been attempted
\ but other units are available in a different theme
\ and the student's results allow entry to those units
\ then recommend alternative unit
\ but record level of interest in Art and previous grades
\ and give explanation to user.
  if
    DoneUnits = AR305 & AR405
    and INTERESTS = Clay
    and DoneUnits # AR302
  \ and GRADES:AR202>WeightedResults = Satisfactory
  then
    RECOMMEND = AR302 <0.75>.
    NoteClay = true.
  endif.
```

AR45\_33 diagnosis:

```
\ if all units in this theme have already been attempted
\ but other units are available in a different theme
\ and the student's results allow entry to those units
\ then recommend alternative unit
\ but record level of interest in Art and previous grades
\ and give explanation to user.
  if
    DoneUnits = AR305 & AR405
    and INTERESTS = Clay
    and DoneUnits # AR303
  \ and GRADES:AR203>WeightedResults = Satisfactory
  then
    RECOMMEND = AR303 <0.75>.
    NoteClay = true.
  endif.
```



*Figure 5.5.1*  
*Art faculty expert system (continued)*

AR42\_43 diagnosis:

```
\ if all units in this theme have already been attempted
\ but other units are available in a different theme
\ and the student's results allow entry to those units
\ then recommend alternative unit
\ but record level of interest in Art and previous grades
\ and give explanation to user.
  if
    DoneUnits = AR402
    and INTERESTS = Printmaking Design
    and DoneUnits # AR403
    and GRADES:AR303>WeightedResults = Satisfactory
  then
    RECOMMEND = AR403 <0.75>.
    NotePrint = true.
  endif.
```

AR42\_45 diagnosis:

```
\ if all units in this theme have already been attempted
\ but other units are available in a different theme
\ and the student's results allow entry to those units
\ then recommend alternative unit
\ but record level of interest in Art and previous grades
\ and give explanation to user.
  if
    DoneUnits = AR402
    and INTERESTS = Printmaking Design
    and DoneUnits # AR405
    and GRADES:AR305>WeightedResults = Satisfactory
  then
    RECOMMEND = AR405 <0.75>.
    NotePrint = true.
  endif.
```

AR43\_42 diagnosis:

```
\ if all units in this theme have already been attempted
\ but other units are available in a different theme
\ and the student's results allow entry to those units
\ then recommend alternative unit
\ but record level of interest in Art and previous grades
\ and give explanation to user.
  if
    DoneUnits = AR403
    and INTERESTS = Drawing Painting
    and DoneUnits # AR402
    and GRADES:AR302>WeightedResults = Satisfactory
  then
    RECOMMEND = AR402 <0.75>.
    NoteDraw = true.
  endif.
```

*Figure 5.5.1*  
*Art faculty expert system (continued)*

```

AR43_45 diagnosis:
\ if all units in this theme have already been attempted
\ but other units are available in a different theme
\ and the student's results allow entry to those units
\ then recommend alternative unit
\ but record level of interest in Art and previous grades
\ and give explanation to user.
    if
        DoneUnits = AR403
        and INTERESTS = Drawing Painting
        and DoneUnits # AR405
        and GRADES:AR305>WeightedResults = Satisfactory
    then
        RECOMMEND = AR405 <0.75>.
        NoteDraw = true.
    endif.

AR45_42 diagnosis:
\ if all units in this theme have already been attempted
\ but other units are available in a different theme
\ and the student's results allow entry to those units
\ then recommend alternative unit
\ but record level of interest in Art and previous grades
\ and give explanation to user.
    if
        DoneUnits = AR405
        and INTERESTS = Clay
        and DoneUnits # AR402
        and GRADES:AR302>WeightedResults = Satisfactory
    then
        RECOMMEND = AR402 <0.75>.
        NoteClay = true.
    endif.

AR45_43 diagnosis:
\ if all units in this theme have already been attempted
\ but other units are available in a different theme
\ and the student's results allow entry to those units
\ then recommend alternative unit
\ but record level of interest in Art and previous grades
\ and give explanation to user.
    if
        DoneUnits = AR405
        and INTERESTS = Clay
        and DoneUnits # AR403
        and GRADES:AR303>WeightedResults = Satisfactory
    then
        RECOMMEND = AR403 <0.75>.
        NoteClay = true.
    endif.

```

\ \*\*\*\*\*

*Figure 5.5.1*  
*Art faculty expert system (continued)*

```

\      Output messages

NPrint details:
  if
  NotePrint = true
  then
  reassert NOTES1 = "*** You wanted to do more Printmaking and Design".
  reassert NOTES2 = " but you have completed all these units".
  reassert NOTES3 = " so we are recommending alternatives. ***".
  endif.

NDraw details:
  if
  NoteDraw = true
  then
  reassert NOTES1 = "*** You wanted to do more Drawing and Painting".
  reassert NOTES2 = " but you have completed all these units".
  reassert NOTES3 = " so we are recommending alternatives. ***".
  endif.

NClay details:
  if
  NoteClay = true
  then
  reassert NOTES1 = "*** You wanted to do more Sculpture and Clay".
  reassert NOTES2 = " but you have completed all these units".
  reassert NOTES3 = " so we are recommending alternatives. ***".
  endif.

A101_8 diagnosis:
  if      RECOMMEND = AR101
        and StudYear = 8
  then    reassert TIMING = "Important and Compulsory".
  endif.

A101_9 diagnosis:
  if      RECOMMEND = AR101
        and StudYear = 9
  then    reassert TIMING = "Urgent and Compulsory".
  endif.

A101_10 diagnosis:
  if      RECOMMEND = AR101
        and StudYear = 10
  then    reassert TIMING = "Urgent and Compulsory".
  endif.

```

*Figure 5.5.1*  
*Art faculty expert system (continued)*

```

Second_8 diagnosis:
  if    ARTcmplt = 1
      and StudYear = 8
  then  reassert TIMING = "Compulsory".
  endif.

Second_9 diagnosis:
  if    ARTcmplt = 1
      and StudYear = 9
  then  reassert TIMING = "Important and Compulsory".
  endif.

Second_10 diagnosis:
  if    ARTcmplt = 1
      and StudYear = 10
  then  reassert TIMING = "Urgent and Compulsory".
  endif.

Last_8 diagnosis:
  if    ARTcmplt = 2
      and StudYear = 8
  then  reassert TIMING = "Compulsory".
  endif.

Last_9 diagnosis:
  if    ARTcmplt = 2
      and StudYear = 9
  then  reassert TIMING = "Important and Compulsory".
  endif.

Last_10 diagnosis:
  if    ARTcmplt = 2
      and StudYear = 10
  then  reassert TIMING = "Urgent and Compulsory".
  endif.

Extension diagnosis:
  if    ARTcmplt ge 3
      and ARTcmplt lt 6
  then  reassert TIMING = "Extension".
  endif.

Specialisation diagnosis:
  if    ARTcmplt ge 6
  then  reassert TIMING = "Specialisation".
  endif.

%
```

*Figure 5.5.1*  
*Art faculty expert system (continued)*

demons:

Stage3 Demon:

```

when ARTcmplt = 3
then erase STAGE.
     STAGE = Stage three.
endwhen.

```

All\_Art\_Done Demon:

```

when ARTjssc = 10
then RECOMMEND = No_AR.
     NOTES1 = "*** You have completed every art unit".
     NOTES2 = " see Mr Dias about Senior Course options.".
     Initial Interests = Printmaking Design.
     INTERESTS = Printmaking Design.
     FEELINGS = Really keen.
endwhen.

```

%

actions:

```

\ In addition to the normal AR units
\ there are multi-level units which need to be recognised

```

```

ARTcmplt = 0.
ARTjssc = 0.

```

```

assertclass GRADES = PAINT, PRINT, No Art.

```

```

MultiUnits = No Multilevel Art.

```

```

read "KES-STU-DATA-PR", DoneUnits.
  if DoneUnits = PRINT
  then
  \       reassert ARTcmplt = ARTcmplt + 1.
  \       reassert ARTjssc = ARTjssc + 1.
  \       reassert MultiUnits = PRINT.
  endif.
  erase DoneUnits.

```

```

read "KES-STU-DATA-PA", DoneUnits.
  if DoneUnits = PAINT
  then
  \       reassert ARTcmplt = ARTcmplt + 1.
  \       reassert ARTjssc = ARTjssc + 1.
  \       if MultiUnits = PRINT
  \       then
  \         reassert MultiUnits = MultiUnits & PAINT.
  \       else
  \         reassert MultiUnits = PAINT.
  \       endif.
  endif.
  erase DoneUnits.
  eraseclass GRADES.

```

*Figure 5.5.1*  
*Art faculty expert system (continued)*

```

read "KES-STU-DATA-AR", StudSName, StudFName, StudYear, CurrTerm,
GRADES, GRADES(RESULTS), DoneUnits.

if MultiUnits = PRINT
  then reassert DoneUnits = DoneUnits & PRINT.
endif.
if MultiUnits = PAINT
  then reassert DoneUnits = DoneUnits & PAINT.
endif.

\ *****

\      Interpretation of raw data from student CBASS records.

forall G:GRADES do
  while G>RESULTS = N do
    erase G>RESULTS.
    message BANNER.
message "Our recommendations take into account your previous units and grades".
message "We already know your past results, but not this term's".
message "Please enter the grade you reasonably expect for ART this term".
    askfor G>RESULTS.
  endwhile.
  if G>RESULTS = A
    then G>WeightedResults = Satisfactory <1.00>.   endif.
  if G>RESULTS = B
    then G>WeightedResults = Satisfactory <0.85>.   endif.
  if G>RESULTS = C
    then G>WeightedResults = Satisfactory <0.70>.   endif.
  if G>RESULTS = D
    then G>WeightedResults = Satisfactory <0.50>.   endif.
  if G>RESULTS = E
    then G>WeightedResults = Unsatisfactory <0.50>. endif.
  if G>RESULTS = W
    then G>WeightedResults = Satisfactory <0.10>.   endif.
endforall.

```

*Figure 5.5.1*  
*Art faculty expert system (continued)*

```

\ Counting JSSC credits and units satisfactorily completed
  if DoneUnits = AR101
    then reassert ARTjssc = ARTjssc + 1.
    endif.
  if DoneUnits = AR202 | PRINT
    then reassert ARTjssc = ARTjssc + 1.
    endif.
  if DoneUnits = AR203
    then reassert ARTjssc = ARTjssc + 1.
    endif.
  if DoneUnits = AR205
    then reassert ARTjssc = ARTjssc + 1.
    endif.
  if DoneUnits = ARBF
    then reassert ARTjssc = ARTjssc + 1.
    endif.
  if DoneUnits = PAINT
    then reassert ARTjssc = ARTjssc + 1.
    endif.
  if DoneUnits = PRINT
    then reassert ARTjssc = ARTjssc + 1.
    endif.

  forall G:GRADES do
    if G>WeightedResults = Satisfactory | Unsatisfactory
      then reassert ARTcmplt = ARTcmplt + 1.
      endif.
    endforall.
  if DoneUnits = No Art
    then reassert ARTcmplt = ARTcmplt - 1.
    endif.

```

\ \*\*\*\*\*

*Figure 5.5.1*  
*Art faculty expert system (continued)*

```

obtain RECOMMEND.

\ *****
\      Screen output.

message BANNER.
message combine ("          Art recommendation summary - ", StudFName).
message "Units thus far ", DoneUnits.
message " ".

if NOTES1 # " "
then  message NOTES1.
      message NOTES2.
      message NOTES3.
      message NOTES4, " ". endif.

if ARTcmplt lt 10
then
message combine ("We recommend that you consider ", RECOMMEND, " ").
message combine ("This recommendation is for ",TIMING," unit/s. ").
endif.

\ *****
\      File output.

write "RcmdAR", TIMING, RECOMMEND.

\ *****
\      Termination

if INFO = Justify
then      justify RECOMMEND.
          message HOLD.
          stop.
          endif.

if INFO = Again
then      nextcase.
          endif.

if INFO = Continue
then      stop.
          endif.

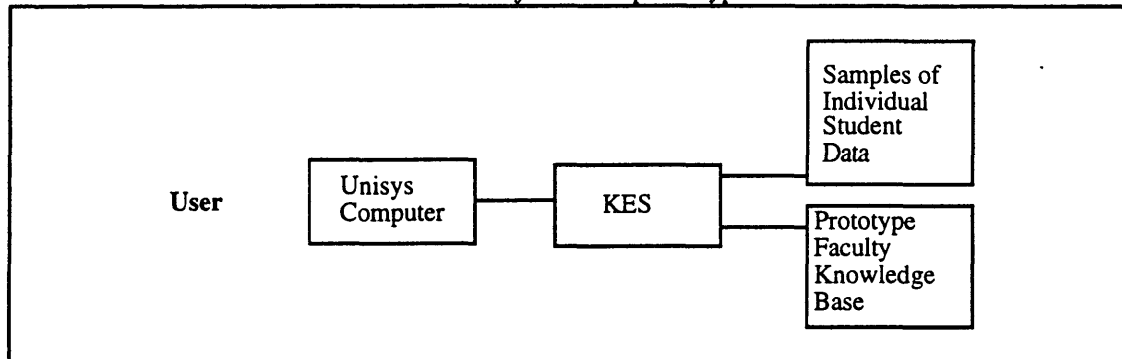
%
```



## 5.7 COMBINED EXPERT SYSTEM

This chapter has described the process by which separate expert systems were developed for each of the school's thirteen subject areas, as per figure 5.7.1.

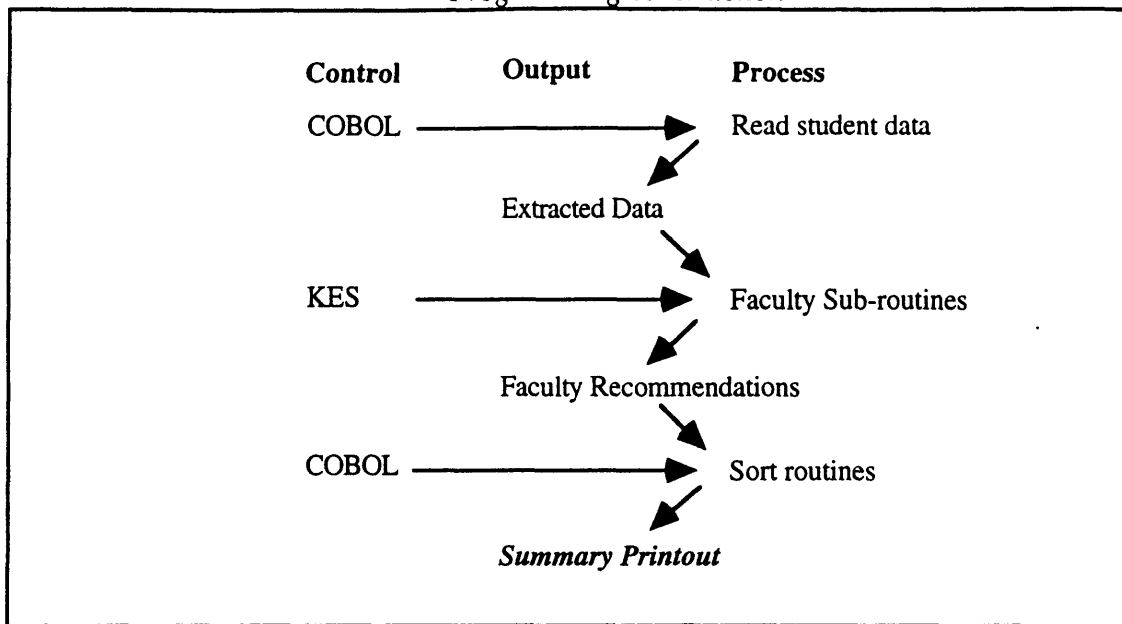
*Figure 5.7.1  
Subject area prototypes*



Although the unit recommendations in some subject areas were influenced by factors in other subject areas, it was considered to be more efficient to construct independent subject systems with appropriate access to other systems rather than prepare an expert system which encompassed all subject areas. In particular, the modular approach enabled subject specialists to examine their domain without the distraction of other subject area details. Further, the time taken by the inference engine to provide recommendations was significantly and exponentially dependant on the volume of data to be examined and thus the modular approach also optimised the operating speed of the subject expert systems.

A control program was prepared as the main user interface to access the student files, call the KES subject area modules, rank priorities for the overall recommendations and provide users with a print-out of recommendations. This process was simple in theory but complicated in practice as KES was written in the programming language C while most of the school's programs were written in COBOL. Because the Northern Territory Department of Education already used COBOL for the student records and had compatible program modules to undertake search routines, these were modified for use in the expert system. Figure 5.7.2 illustrates the program paradigm used to accommodate these factors.

*Figure 5.7.2  
Programming construction*



KES did not have the facilities to integrate these control functions and thus alternative software was required. KES is written in the C programming language and thus can be embedded into other software written in C to enable KES to operate as a module of the control program with effective internal communications and the ability to modify the user-interface. Despite the potential advantages of using C, the version of C used in KES was much earlier than that currently in use at Northern Territory schools and thus would require a special application. It was considered expeditious to use the computer's operating system (CTOS - Convergent Technology Operating System) for the control program. Thus rather than use an embedded software system, as shown in figure 5.7.3, the linked model shown in figure 5.7.4 was prepared.

*Figure 5.7.3  
Embedded software model*

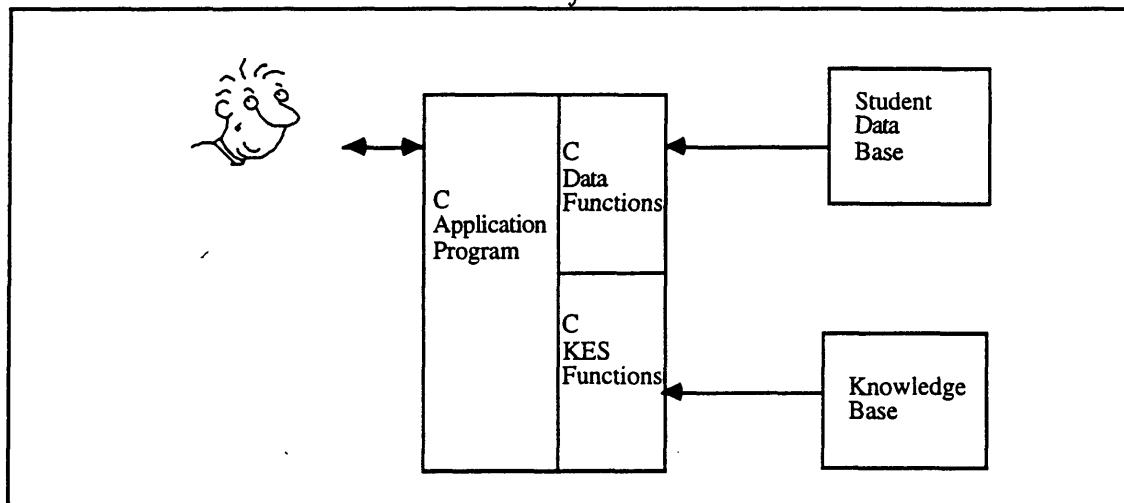
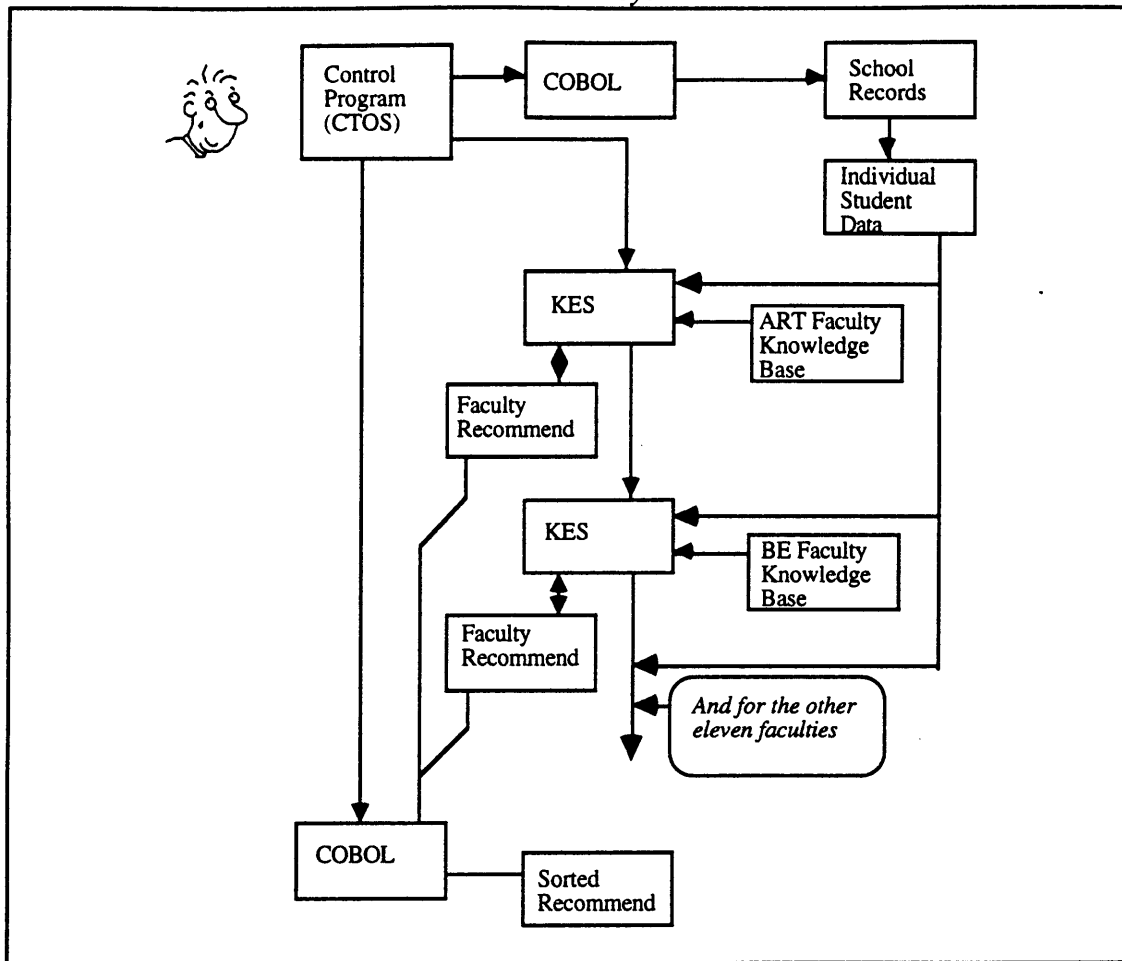


Figure 5.7.4  
Linked systems



The CTOS operating system was used to seamlessly move the user from one stage to the next. Figure 5.7.5 contains the actual programming code for this routine. The main disadvantage in this process is the short delay while individual programs are loaded. This is most obvious when running the thirteen KES routines (one for each subject area) as the standard program introduction message appears on the screen each time. This fault was not considered significant for a prototype expert system and could be overcome for a marketable product by using C for the control program; but, as the researcher had no training in C, this was not done for the RUS system.

*Figure 5.7.5*  
*RUS programming code*

```

$ JOB SysInit
$ ECHOSOME

$COMMAND KESR, NEXT-BLANK
$RUN ([SYS]<COBOL2>COBOL/2.RUN,'C/2 RUN'),STUDATA2.INT
$COMMAND KESR, NEXT-EN
$COMMAND KESR, NEXT-MA
$COMMAND KESR, NEXT-SA
$COMMAND KESR, NEXT-SC
$COMMAND KESR, NEXT-LOTE
$COMMAND KESR, NEXT-AR
$COMMAND KESR, NEXT-BE
$COMMAND KESR, NEXT-CO
$COMMAND KESR, NEXT-DR
$COMMAND KESR, NEXT-MS
$COMMAND KESR, NEXT-TS
$COMMAND KESR, NEXT-PE
$RUN ([SYS]<COBOL2>COBOL/2.RUN,'C/2 RUN'),RUARY3.INT

$END

```

The RUS programming code listed in figure 5.7.5 is activated from the computer's sign-on screen and functions at the computer's operating system level. The first two lines of code establish the task and screen control. The next block of code provides the instructions for the various tasks to be undertaken. The first command starts the KES run-time program (KESR) with the knowledge base NEXT-BLANK, which creates a student file containing blank data for each field. The instruction is then given to run the COBOL program STUDATA2.INT in which a student is selected from the school roll and that student's subject enrolment and assessment data is extracted to replace the blank data where appropriate. The next group of commands run the KESR program for each of the subject areas, during which each of the subject recommendations is written to a file. Then the instruction is given to run the COBOL program RUARY3.INT which sorts and prints the subject recommendations. The RUS system required users to examine every subject area. Consideration was given to allowing users to select subject areas, but was discounted because subject and unit avoidance was one problem the expert system was intended to overcome.

The following screen dumps taken from the RUS system illustrate the user interface of this expert system.

- |               |                                     |
|---------------|-------------------------------------|
| Figure 5.7.6  | RUS Sign-on screen                  |
| Figure 5.7.7  | RUS Student selection screen        |
| Figure 5.7.8  | RUS English screen extract          |
| Figure 5.7.9  | RUS Science screen extract          |
| Figure 5.7.10 | RUS Social Education screen extract |
| Figure 5.7.11 | RUS Mathematics screen extract 1    |
| Figure 5.7.12 | RUS Mathematics screen extract 2    |

SignOn 12.2.0 (OS pSvr 3.4.4)

Fri Aug 13, 1993 8:49 AM

RUARY'S CTOS II Machine - 10/8/93.

User name	Enter a user name, an application name, or leave this line     blank to display a Command prompt.
Password	Enter your assigned password (optional).
Day/Date/Time	Enter the current day, date and time (if not already set).
Environment	Enter the name of the user environment (optional).

Then press the GO key.

User name (e.g., Pam)

RUS

Password

Date/Time (e.g., Fri Dec 13, 1991 10:00 am)

User environment

Executive 12.2.0 (OS pSrvr 3.4.4)  
Path: [Sys]Kkas)

Replaying User: rus  
Fri Aug 13, 1993 8:11 AM

Ruary's KES System

Student Name Search (12B)

Student Surname :

Line No.	Student Number	First given Name	Second given Name	Year	Home Group	Birthdate	Date Left
01	00190			09	210	24/	
02	00151	KRISTIN		09	311	08/04	
						/ /	
						/ /	
						/ /	
						/ /	
						/ /	
						/ /	
						/ /	

Enter line no to select that student:

CANCEL = Cancel current transaction

FINISH = Exit program

Executive 12.2.0 (OS pSrvr 3.4.4)  
Path: [Sys]kes>

Replaying User: rus  
Fri Aug 13, 1993 9:43 AM

Our recommendations take into account your previous units and grades  
We already know your past results, but not this term's  
Please enter the grade you reasonably expect for ENGLISH this term

For 'EN215' of class 'GRADES':

RESULTS

1. A
2. B
3. C
4. D
5. E
6. W
7. N

=? 2

\*\*\*\*\*

English recommendation summary - KRISTIN

Units thus far

EN201 <1.00>, EN202 <0.85>, EN111 <0.85>, EN102 <0.85>, EN101 <0.85>, EN205  
<0.50>, and EN215 <0.50>

We recommend that you consider EN309 <1.00>, EN307 <1.00>, EN308 <1.00>,  
EN306 <1.00>, EN305 <1.00>, EN304 <1.00>, EN303 <1.00>, EN302 <1.00>, and  
EN301 <1.00>

This recommendation considers Urgent and Compulsory unit/s.

What would you like to do now?

1. Explain the recommendation.
2. Enter new information about your preferences.
3. Continue with the next subject area.

=?

Which of these Science groups would you prefer next term?

1. Geology and minerals
2. Biology and environmental studies
3. Chemistry
4. Physics

=? 2

\*\*\*\*\*

Science recommendation summary - KRISTIN

Units thus far

SC1B <0.85>, SC1I <0.85>, SC1P <0.60>, SC1E <0.60>, SC1C <0.60>, and SC2E <0.40>

We recommend that you consider SC2B <1.00>

This recommendation considers Important and Compulsory unit/s.

What would you like to do now?

1. Explain the recommendation.
2. Enter new information about your preferences.
3. Continue with the next subject area.

=?



Executive 12.2.0 (OS pSrvr 3.4.4)  
Path: [Sys]kes>

Replaying User: rus  
Fri Aug 13, 1993 8:43 AM

=====

We already know your past results, but not this term's  
Please enter the grade you reasonably expect for Social education this term

For 'SA340' of class 'GRADES':

RESULTS

1. A
2. B
3. C
4. D
5. E
6. W
7. N

=? why

KES is asking for a value for 'GRADES:SA340>RESULTS' because:

A command in the actions section or an interactively  
specified command is assigning a value to 'GRADES:SA340>RESULTS'.

Resuming deferred questioning...

Please reenter value:

For 'SA340' of class 'GRADES':

RESULTS

1. A
2. B
3. C
4. D
5. E
6. W
7. N

=?

Our recommendations take into account your previous units and grades  
We already know your past results, but not this term's  
Please enter the grade you reasonably expect for MATHS this term

For 'MA3ML' of class 'GRADES':

RESULTS

- 1. A
  - 2. B
  - 3. C
  - 4. D
  - 5. E
  - 6. W
  - 7. N
- =? 2

What are your feelings towards doing Mathematics next term?

- 1. Really keen
  - 2. Enjoy it
  - 3. Its okay
  - 4. Prefer not
  - 5. Definitely not
- =? 2

Which of these Mathematics units would you prefer next term?

- 1. Space and Measurement
  - 2. Algebra and Number
  - 3. Essential for daily use
- =? 2

Which level do you wish to complete by the end of Year 10?

- 1. Level 1 which concentrates on theoretical maths  
and leads to Maths A in year 11.
  - 2. Level 2 which combines theoretical and daily use maths  
and leads to Foundation Maths in Year 11.
  - 3. Level 3 which concentrates on maths for daily use  
and leads on to Access Maths after Year Ten.
- =? 2

\*\*\*\*\*

Mathematics recommendation summary - KRISTIN

Units thus far

MA24D <0.85>, MA13T <0.85>, MA12T <0.85>, MA34D <0.60>, MA23D <0.60>, MA3ML  
<0.50>, and MA33D <0.40>

We recommend that you apply for MA4UL <1.00> and MA44D <0.50>

This recommendation is for Urgent and Compulsory unit/s.

What would you like to do now?

- 1. Explain the recommendation.
  - 2. Enter new information about your preferences.
  - 3. Continue with the next subject area.
- =?

Executive 12.2.0 (OS pSrvr 3.4.4)  
Path: [Sys]\  
(kes)

Replaying

User: rus  
Fri Aug 13, 1993 8:43 AM

=====

3. Continue with the next subject area.  
=? 1

RECOMMEND = MA4UL <1.00>

Reasons for belief:  
rule: M4UL diagnosis

Would you like to see the supporting knowledge sources and demons? (y/n) y

Name: M4UL diagnosis  
Kind of entity: Production Rule

\ If a student has done well in two Stage Three units  
\ and the student has selected Essential maths  
\ or has not selected Level One  
\ and has not attempted MA4UL then this unit is recommended.  
if  
  MathsStageThreeCapIt ge 2  
  and DoneUnits # MA4UL  
  and INTERESTS = Essential  
  or INTENDED LEVEL # L1  
  then  
    RECOMMEND = MA4UL.  
  endif.

People using the RUS system were required to proceed through all the faculty areas. Within each faculty there was an opportunity to vary input in response to the recommendations made for that faculty and thus explore alternative pathways. A printed report of the faculty recommendations was provided after users completed all the faculty expert systems. The printed report, as per figure 5.7.13, grouped the recommendations by priority to further highlight the need for users to be aware of the overall requirements.

*Figure 5.7.13*  
*Sample of Student Recommendation Report*

**Recommending Unit Selection**

The recommendations that you examined in the various subject areas are printed below for your use. It is suggested that you refer to the *Dripstone Course Outlines* handbook to find out the details of these units before making your choices for next term.

The recommendations for subject areas are listed under six headings:

**Urgent and Compulsory**  
You still have compulsory units and it is urgent to enrol in at least one now.

**Important and Compulsory**  
You still have compulsory units and it is important to enrol in one soon.

**Compulsory**  
You still have compulsory units to be completed for your JSSC.

**Extension**  
You have completed all the compulsory units and these are additional studies.

**Specialisation**  
You have already done some extension units and are now really specialising.

The numbers after each unit indicate the importance of the recommendation, the higher the number the stronger the recommendation.

**Kristan xx    Year xx**

**Urgent and Compulsory**  
EN309 <100>    EN307 <100>    EN308 <100>    EN306 <100>    EN305 <100>  
MA4UL <100>    MA44D <50>

**Important and Compulsory**  
AR205 <85>    AR202 <85>  
BE110 <100>  
IN213 <100>    IN212 <75>    IN211 <75>    IN210 <75>  
SA341 <100>    SA331 <100>    SA321 <100>    SA320 <100>  
SC2B <100>

**Compulsory**  
DR220 <30>  
MS240 <15>

**Extension**  
CO200 <50>  
HE220 <18>  
PE230 <15>    PE220 <15>  
TS130 <100>

**Specialisation**

## 5.8 CONCLUSION

The research methodology was applied to enable school personnel to construct an expert system for use at the trial school. The main elements of this methodology were (1) the preparation of paper and computer formal models from the various mental models used by the personnel concerned, and (2) the construction of the expert system utilising these models in its knowledge-base.

The domain knowledge was represented in three main formats: the models which had already been prepared by the school for its own purposes, a series of development models which were used in the construction of the expert systems, and the RUS system which used a rule structure. These formats were designed to tease out the mental models and provide a formal model which could be evaluated and modified without the need for technical expertise.

The toolkit KES II enabled the development of an expert system for the research project. The features available, though probably not fully used, enabled the wide range of elicited knowledge to be represented and used in a competent user-friendly manner.

## **Chapter 6**

### **EVALUATION OF THE WORKING SYSTEM**

#### **6.1 INTRODUCTION**

An important responsibility of schools is to ensure that students undertake studies that comply with certification requirements. Schools with a unitised curriculum and a vertical timetable have a particularly complex task to ensure such compliance when students have the opportunity to select courses rather than follow an established pattern. The RUS system developed in this project was intended to provide subject selection recommendations in response to student preferences and also take into account the need to meet subject, school and certification requirements.

Effective use of a system, manual or computerised, will depend on the reliability of the system and the design of its user-interface. Thus it was appropriate to evaluate the RUS system to validate its recommendations and compare the reliability of these recommendations against those made by the current manual system with human experts. It was also appropriate to gauge users' reactions to using a computerised expert system as an alternative to the current manual procedures.

Previous chapters examined the broader aspects of evaluation and summarised the procedures adopted for this research. This chapter examines the evaluation instruments which were used: (1) to compare the recommendations made by the RUS system with actual outcomes, and (2) to elicit user response to the RUS system.

#### **6.2 VALIDATION OF THE EXPERT SYSTEM**

Teaching staff participated in the preparation and publication of the faculty flow charts and descriptors, and were actively involved in evaluations during the development of the faculty expert systems and of the final expert system. In particular, the faculty co-ordinators were provided with copies of the construction models and participated in individual discussions on the model's contents.

The first formal evaluation of the expert system was conducted at the end of second term 1993 when a blind evaluation was undertaken with data for 50 students. These students were selected on the following basis: commencing with surnames starting with A, the first five students of that and subsequent letters were used, except that no more than two year eight students were selected from each letter and at least one year nine and one year ten student were selected from each letter. Five students left the school during the evaluation period and were replaced with five more students selected using the same process.

The data for these students were used to compare the RUS system with the current manual system. In particular, the actual student placements for the following term were compared with recommendations by the expert system, with a view to testing the validity of the output from each system.

The retrospective comparison involved a detailed examination of the student's status under the current manual system. The expert system recommendations were based on presumed answers for questions that the program would have asked these students. For anticipated grades the students' actual grades were entered, and for subject interests the answers were based on the actual placements; for example, if a student had been placed in a Geography unit then it was presumed that the student would have expressed at least some interest in Geography.

This evaluation, illustrated in figure 6.2.1, was undertaken to determine (1) a correlation between the actual subjects studied and the RUS recommendations, and (2) a correlation between the actual units studied within subjects. Differences between these were examined to determine the reason for discrepancies and the implications of these variances.

*Figure 6.2.1  
Comparison of some actual outcomes and recommendations for one student*

Name	Subject	AR	BE	CO	DR	EN
Yr - 8	Core	3	1	0	1 - 2	10
	Number	1	1	0	0	1
	Term 2					B
	R-T	2	4	4	3	1
	Term 3				DR110	EN122
	R-U				1	6

#### Legend

Subject	Code for subject area examined in that column
Core	Minimum number of units required in this subject area
Number	Number of units attempted thus far, including current units
Term 2	Grade achieved for units undertaken in second term
R-T	Recommended Timing by E.S.
	1 Urgent & Compulsory
	2 Important & Compulsory
	3 Compulsory
	4 Extension
	5 Specialisation
Term 3	Actual subject allocation
R-U	Number of units in this subject recommended by expert system

In this example, a year eight student has previously done one of the minimum three Art (AR) units, was not doing Art in second term, and the expert system reminded the student that there were other compulsory Art units to be completed and that the timing was important. The student had completed the one compulsory Business Education (BE) unit and any future studies in this subject would be extension units. There are no compulsory Computing (CO) units, and the student has not enrolled in any Computing units. The student had not previously undertaken any of the one or two compulsory Drama (DR) units (students must attempt at least one Drama and one Music unit, plus another Drama or Music unit) but was enrolled to study Drama 110 in third term. This was the only Drama recommendation that would have been made by the RUS system which would have also reminded the student of the need to complete one of the compulsory Drama units. The student had previously completed one of the ten compulsory units for English (EN) and in second term achieved a B for the unit being studied. The expert system recommended six English units for consideration for third term and recommended an Urgent timing priority for English. The student was enrolled in one of these six units for the following term.

Table 6.2.1 on the following ten pages provides the data for all fifty students.



**Coding for Table details**

	Subject		AR											
1 A	Core		3											
Name	Term 2		B											
Yr - 10	R-T		4											
93	Term 3		330											
	R-U		2											

**Name** Names have been deleted, though coding left for future reference  
**Yr - 93** Current year level (8, 9, or 10)  
 If present, this indicates year 9 or year 10 students who commenced at the school this year, and thus might not satisfy minimum unit requirements

**Subject Core** Code for subject area examined in that column (see below for details)  
 Minimum number of units required to complete Core Curriculum in this subject area

**Number Term 2 R-T** Number of units attempted thus far, including current units  
 Grade achieved for units undertaken in second term  
 RUS Recommended Timing  
 1 Urgent & Compulsory  
 2 Important & Compulsory  
 3 Compulsory  
 4 Extension  
 5 Specialisation

**Term 3 R-U** Actual subject allocation (usually based on student preferences)  
 Number of units recommended by RUS

**##** Problems which are explained further in the Appendix 3 notes

**Subject area** Minimum units required for Year 10 certificate

AR	Art	3
BE	Business Education	1
CO	Computing	0
DR	Drama	1 (plus another if only 1 Music)
EN	English	10
HE	Home Economics	2
LOTE	Languages Other Than EN	4 (3 for current Year 10 students)
MA	Mathematics	10
MS	Music	1 (plus another if only 1 Drama)
PE	Physical Education & Health	5 (3 for current Year 10 students)
SA	Social Education	9
SC	Science	9
TS	Technical Studies	2

Subject	AR	BE	CO	DR	EN	HE	LOTE	MA	MS	PE	SA	SC	TS
Core	3	1	0	1-2	10	2	3-4	10	1-2	3-5	9	9	2
Number	1	1	0	0	1	1	1	2	0	0	2	2	0
Term 2					B	B	D	C	C	D	D	C	
Yr - 8	R-T	4	4	4	3	3	1	1	3	1	1	1	3
Term 3					122	122	24D	24D	125	210	18		
R-U					6	6	1	1	3	6	1		
Number	2	0	0	0	1	2	2	6	1	2	6	2	
Term 2					A	A	D	D	B	C	D	D	
Yr - 9	R-T	1	4	3	1	1	1	1	4	1	2	2	4
Term 3					215	11	IT	3ML	140	340			
R-U					5	1	4	1	6				
Number	2	0	0	1	6	2	2	6	1	2	6	2	
Term 2					A	A	D	D	B	C	D	D	
Yr - 9	R-T	2	4	3	1	1	1	1	4	1	2	2	4
Term 3					100	215	IT	3ML	140	340			
R-U					1	5	1	4	1	6			
Number	1	1	0	0	2	2	1	2	0	1	2	2	
Term 2					D	D	C	C	A	C	D	D	
Yr - 8	R-T	1	4	3	1	1	1	3	1	1	1	1	3
Term 3					122	122	24D	24D	110	210	18		
R-U					6	6	2	2	1	6	1		
Number	3	1	0	0	2	1	1	2	0	2	2	2	
Term 2					A	D	C	C	A	C	D	D	
Yr - 8	R-T	2	4	3	1	3	1	3	3	1	1	1	3
Term 3					122	122	24D	24D	110	210	18		
R-U					6	6	2	2	1	6	1		
Number	3	1	0	0	2	1	1	2	0	2	2	2	
Term 2					D	D	C	C	A	C	D	D	
Yr - 10	R-T	1	4	4	1	4	4	4	4	1	4	4	
Term 3					309	423	na	na	na	Money	220		
R-U					2	2	2	2	2	3	1		
Number	1	0	0	0	2	2	2	2	0	2	2	1	
Term 2					A	B	B	B	C	C	B	B	
Yr - 8	R-T	2	4	3	1	4	4	1	1	1	1	1	3
Term 3					103	120	24D	24D	110	240	18		
R-U					6	6	1	1	1	6	1		
Number	1	0	1	0	2	2	1	2	1	2	6	2	
Term 2					B	B	C	C	A	C	B	B	
Yr - 9	R-T	4	3	4	1	3	1	1	4	1	2	2	4
Term 3					214	214	43D	43D	IN110	340	2B	2	
R-U					3	3	1	1	1	6	1		
Number	1	1	1	1	6	2	1	6	1	3	6	6	
Term 2					A	B	C	C	A	B	A	A	
Yr - 9	R-T	4	3	4	1	4	2	2	4	2	2	2	4
Term 3					214	214	43D	43D	IN110	340	2B	2	
R-U					3	3	1	1	1	6	1		

	Subject Core	AR 3	BE 1	CO 0	DR 1-2	EN 10	HE 2	LOTE 3-4	MA 10	MS 1-2	PE 3-5	SA 9	SC 9	TS 2
7	Number Term 2	1	0	0	1	2 C	1	0	1 B	2 A A	0	2 A	2 C	0
Yr - 8	R-T Term 3	3	1	4	3	1	3	3	1	4	1	1	1	3
	R-U					103 6			13T 3		110 3	240 6	1P 1	110 2
8	Number Term 2	0	1	0	0	2 B	0	1	2 B	1	0	2 A	2 C	1 C
Yr - 8	R-T Term 3	2	4	4	3	1	3	2	1	4	1	1	1	3
	R-U				110 1	111 ## - 6			24D 1		125 3	231 6	1P 1	
9	Number Term 2	1	1	0	1	6 A	1	2	6 C	1	2 B	6 B	6 C	2
Yr - 9	R-T Term 3	2	4	4	3	1	3	2	1	4	1	2	2	4
	R-U			200 ## - 1		214 10		IN212 4	44D 2		110 1	320 6		
10	Number Term 2	1	1	0	1	6 A	2	2	6 C	1	3	5 C	6 C	1
Yr - 9	R-T Term 3	2	4	4	3	1	4	2	1	3	2	1	2	3
	R-U				140 1	214 5			44D 2		Teamsp 2	220 3	2B 1	
11	Number Term 2	3	1	0	1	7 C	2	1	na B	1	2 A	6 C	5+1 C	2 C
Yr - 10	R-T Term 3	4	4	4	2	1	4	1		3	1	1	1	5
	R-U					309 6			331		125 1	340 6	2B 2	220 2
12	Number Term 2	4	1	0	1	9 C	2	4	na C	1	2	10 C	9** D	5** C
Yr - 10	R-T Term 3	4	4	4	1	1	4	4		1	1	4	4	4
	R-U				##	303 ## - 4			426	##	Teamsp 1	431 3		220 2

	Subject	AR	BE	CO	DR	EN	HE	LOTE	MA	MS	PE	SA	SC	TS
	Core	3	1	0	1-2	10	2	3-4	10	1-2	3-5	9	9	2
13	Number	2	1	0	1	6	2	1	6	1	3	6	6	1
	Term 2	A				C			B		B	C		
Yr - 9	R-T	2	4	4	3	1	4	2	1	3	2	1	2	3
	Term 3				140	221			43D		290	310	2C	
	R-U				1	3			2		2	6	## - 1	
14	Number	1	0	0	0	## 2	1	0	2	0	1	2	2##	1
	Term 2	D				E			E		E	E	E	
Yr - 8	R-T	3	1	4	3	1	3	1	1	3	1	1	1	3
	Term 3					131		IN110	RR13M		125		1CR	
	R-U					## - 6		1	4		2		2	
15	Number	4 - ##	1	1	1	8	2	3	na	5	3	8	10	3
	Term 2	B				E			C	A		A	A	
Yr - 10	R-T	4	4	4	4	1	4	4		5	4	1	4	4
	Term 3					309			413	110		431	3P	
	Term 3											\$\$110		
	R-U					4				3		5	1	
16	Number	2	1	0	1	6	1	1	6	1	2+1	6	6	2
	Term 2		B			C			C		A	C	C	
Yr - 9	R-T	1	4	4	3	1	3	1	1	3	1	2	2	4
	Term 3					205		IT	44D		Team ##		2B	
	R-U					9		1	1		1		1	
17	Number	1	1	0	1	6	2	1	6	1	3+1	6	5+1	1
	Term 2					E			E		A	E	E	C
Yr - 9	R-T	2	4	4	3	1	4	1	1	3	2	2	2	3
	Term 3				320	205		IN212	34D			210	1C	
	R-U				## - 1	5		4	## - 0			6	1	
18	Number	2	1	0	1	10	3	2+1	na	1	4+1	10	12	2
	Term 2					B			A		A	A	A A	
Yr - 10	R-T	1	4	4	1	1	4	4		1	4	4	5	4
	Term 3	Paint			200	##			413	##		Money	3P	
	R-U	2			## - 1	3						3	1	

	Subject	AR	BE	CO	DR	EN	HE	LOTE	MA	MS	PE	SA	SC	TS
	Core	3	1	0	1-2	10	2	3-4	10	1-2	3-5	9	9	2
19	Number	2	0	0	2	6	1	3	##	0	3	6	5+1	1
	Term 2	B				B	B		C			C	C	
Yr - 9	R-T	2	1	4	4	1	3	2	1	1	2	2	2	3
	Term 3					214			3ML		Teamsp	320	2B	130
	R-U					4			2		2	6	1	1
20	Number	1	0	0	0	2	1	1	2	0	0	2	2	1
	Term 2					C	A	B	C			C	C	
Yr - 8	R-T	3	1	4	3	1	3	2	1	3	1	1	1	3
	Term 3				110	103			24D	110		210	1B	
	R-U				1	6			1	1		6	1	
21	Number	3	1	0	2	8	2	2	na	1	4	8	8	1
	Term 2					D			E C	C		C	E	
Yr - 10	R-T	4	4	4	4	1	4	1		4	4	1	1	1
	Term 3					309		##	426		Teamsp	330	3AA	##
	Term 3												2P	
	R-U					2					2	5	## - 4	
22	Number	2	1	0	1	6	2	1	6	1	2	6	6	2
	Term 2	A				C			C			B	C	A
Yr - 9	R-T	2	4	4	3	1	4	1	1	3	1	2	2	4
	Term 3					221		IN212	43D		125	310	2C	
	R-U					8		4	1		1	6	## - 2	
23	Number	2 + 1	1	0	1	10	2	2 ##	na	4	3	10	9	6
	Term 2	A				C			B	C		B	B	B
Yr - 10	R-T	4	4	4	4	1	4	1		5	4	4	4	5
	Term 3	Paint				309		##	426		Teamsp	Money		220 ##
	R-U	2				2					2	2		1
24	Number	2	1	1	1	9	2	3	na	1	3	9	9	2
	Term 2					B B			A		A	B	A	
Yr - 10	R-T	1	4	4	1	1	4	4		1	4	4	1	4
1992	Term 3	##			##	308			413	##	##	Law	3P	
	Term 3											310	3C	
	R-U					8						4	## - 1	

	Subject Core	AR	BE	CO	DR	EN	HE	LOTE	MA	MS	PE	SA	SC	TS
		3	1	0	1-2	10	2	3-4	10	1-2	3-5	9	9	2
25	Number	0	0	0	0	2	0	2	2	1	0	2	2	1
	Term 2					B		A	A			B	A	A
Yr - 8	R-T	2	1	4	3	1	3	2	1	3	1	1	1	3
	Term 3					111	120		23D		110	240	1E	
	R-U					2	2		2		3	6	1	
26	Number	2	0	0	1	8##	1	1##	na	0	4##	4##	5##	2
	Term 2					E		E	D		A	C	E	
Yr - 10	R-T	1	1	4	1	1	2	1		1	1	1	1	4
1993	Term 3	Paint				309			331	110	230	Money		
	R-U	2				6				1	##-2	5		
27	Number	4	1	0	2	9	3	2	na	1	3	10	9+1	4
	Term 2	B				D			D			C	B	B
Yr - 10	R-T	4	4	4	1	1	4	1		1	4	4	3	4
	Term 3					309		IN212	331			Law	2E	
	Term 3											330		
	R-U					2		4				4	2	
28	Number	1	0	0	0	2	0	0	2	2	0	2	2	1
	Term 2	A				B			C	A		B	C	
Yr - 8	R-T	3	1	4	3	1	3	1	1	4	1	1	1	3
	Term 3					103		IN110	23D		110	240	1C	
	R-U					6		1	1		3	6	1	
29	Number	1	1	0	0	2	0	1	2	0	0	2	2	1
	Term 2	C	C			E			C			D	C	
Yr - 8	R-T	3	4	4	3	1	3	3	1	3	1	1	1	3
	Term 3					122			23D	110	110	240	1B	
	R-U					6			1	1	3	6	1	
30	Number	1	0	0	0	2	0	3	2	1	1	2	2	2
	Term 2	B				B		B	B			C	B	
Yr - 8	R-T	3	1	4	3	1	3	4	1	3	1	1	1	4
	Term 3					122	110		24D		110	210	1C	
	R-U					##-2	2		2		3	6	1	

	Subject	AR	BE	CO	DR	EN	HE	LOTE	MA	MS	PE	SA	SC	TS
	Core	3	1	0	1-2	10	2	3-4	10	1-2	3-5	9	9	2
31	Number	4 ##	1	0	3	10	3	2	na	1	5 ##	9	10	2
	Term 2				A	B			B	B	B		B	
Yr - 10	R-T	4	4	4	4	4	4	1		4	4	1	4	4
	Term 3	Print				309		##	423			Money		
	Term 3	Paint										330		
	R-U	2				## - 5						2		
32	Number	3	0	0	3	6	2	1	5+1	3	2	4	5	1
	Term 2													
Yr - 9	R-T	4	1	4	4	1	4	1	1	4	1	1	2	3
	Term 3		110			215			34D		125	231	2B	
	R-U		1			3			2		1	4	1	
33	Number	1	1	0	2	6	2	1	6	1	3	5	6	2
	Term 2					C			C		CC	C	E	
Yr - 9	R-T	2	4	4	4	1	4	2	1	4	2	1	2	4
	Term 3	Sculpt				221			3ML		Team	240	2B	
	R-U	3				9			2		2	3	1	
34	Number	1	0	0		4	2	2		##	2	##	5	1
	Term 2													
Yr - 9	R-T	2	1	4		1	4	2			1		2	3
Spec Unit	Term 3	Print				205			RR31M		110	240		
	R-U	3				5					1			
35	Number	3	1	0	1	10	2	5	na	1	4+1	10	10	4
	Term 2					C			B		A	B	C	B
Yr - 10	R-T	4	4	4	2	1	4	4		3	4	4	4	5
	Term 3	Print			##	309			423	##	230	Money		220
	R-U	1				2					## - 2	2		1
36	Number	4	1	2	2	9	2	3	na	1	2 ##	9	10	4
	Term 2					B		C	B			B C	B	
Yr - 10	R-T	4	4	4	4	1	4	4		4	1	4	4	5
	Term 3	Print				309			423		140	310		240
	R-U	3				3					1	## - 2		1

Subject	AR	BE	CO	DR	EN	HE	LOTE	MA	MS	PE	SA	SC	TS
37	Number	1	0	0	1	1	0	2	0	1	2	2	1
Yr - 8	Term 2	C	C	C	D	D	D	D	C	C	D	E	C
	R-T	3	1	4	3	1	1	1	3	1	1	1	3
	Term 3				IN10	IN10	13T	13T		110	231	ICR	
	R-U				## - 1	## - 1	3	3	2	2	6	## - 2	
38	Number	2	1	0	1	2	1	6	1	2	6	6	2
Yr - 9	Term 2	C	C	C	D	D	D	C	C	C	E	E	2
	R-T	2	4	4	3	1	1	1	3	1	2	2	4
	Term 3				205	3ML	24D	Teamp	310	2B			
	R-U				3	2	6	1					
39	Number	4	1	0	1	2	2	9	1	5	6##	8	3
Yr - 10	Term 2				D	C	C	C	C	C	E	E	3
	R-T	4	4	4	1	4	1	1	3	1	1	1	4
	Term 3	Prnt			303	##	426	##		320	2E		
	R-U	1			## - 4					340			
40	Number	1	1	0	1	6	2	2	1	3	5	7	1
Yr - 9	Term 2	A	A	A	B	C	C	A	A	A	A	A	1
	R-T	2	4	4	1	4	2	2	3	2	1	3	3
	Term 3	Prnt			215	IT	44D	240		240	2P		
	R-U	3			3	1	2	3		3	1		
41	Number	1	1	0	2	2	2	6	1	2	6	6	1
Yr - 9	Term 2	B	B	D	D	B	B	B	B	C	C	C	3
	R-T	2	4	4	1	4	2	1	4	1	2	2	3
	Term 3				215	44D	125	330		330	2E		
	R-U				11	1		5		1	1		1
42	Number	6	1	0	1	2	4	9	1	4	8	8	6
Yr - 10	Term 2	A		C	C	C	na	C	A	A	C	C	5
	R-T	5	4	4	1	4	4	1	3	4	1	1	5
	Term 3				309	426		426		230	3AA	220	1
	R-U				2					2	4		1



	Subject Core	AR	BE	CO	DR	EN	HE	LOTE	MA	MS	PE	SA	SC	TS
		3	1	0	1-2	10	2	3-4	10	1-2	3-5	9	9	2
43	Number	1	1	0	1	6	2	3	6	2	2	6	6	1
	Term 2					B		C	C		C	C	C	
Yr - 9	R-T	2	4	4	4	1	4	3	1	4	1	2	2	3
	Term 3					205			44D		125	320	2E	110
	R-U					9			2		1	6	1	1
44	Number	2	1	0	1	5	2	1	6	2	3	6	6	2
	Term 2					C	B		C		C	C	C	
Yr - 9	R-T	2	4	4	4	1	4	2	1	4	2	2	1	4
	Term 3	Sculpt				221		IN212	43D			330	1P	
	R-U	2				9		4	1			5	1	
45	Number	2	1	0	1	10	2	3	na	1	4	9	10	4
	Term 2					C			C			A B	C	A
Yr - 10	R-T	1	4	4	2	1	4	4		3	4	4	4	5
	Term 3	Print				309			413		Teamsp	310	3C	
	R-U	2				2					3	## - 2	1	
46	Number	1	1	0	##	6	2	1	6	1	2	6	6	2
	Term 2	B			C	C			C			C	C	
Yr - 9	R-T	2	4	4	2	1	4	2	1	3	1	2	2	4
	Term 3	Print				221			44D		110	310	2P	
	R-U	3				4			2		1	6	1	
47	Number	2	1	0	1	6	2	3	6	1	0##	6	6	2
	Term 2	B				B			B			B	B	B
Yr - 9	R-T	2	4	4	3	1	4	3	1	3	1	2	2	4
	Term 3	Print				221	223		44D		##	320	2E	
	R-U	3				9	1		1			6	1	
48	Number	1##	0	0	0	2	1	0	2	1	1	2	2	1
	Term 2					A			A	A		B	A	A
Yr - 8	R-T	3	1	4	3	1	3	3	1	3	1	1	1	3
	Term 3	101				111		IT	23D			240	1B	
	R-U	1				2		1	1			6	1	



An analysis (table 6.2.2 on the following three pages) of table 6.2.1 revealed a variety of problems arising from the manual system. Some of these problems question the validity of some current student placements, while some problems raise doubts about the verification procedures for current record keeping.

- (1) Ten of the sixteen year ten students were undertaking extension units without having completed all their compulsory units and thus would have to be careful in their term four selections in order to satisfy the certification requirements. These students probably had sufficient time to enrol in the missing units and thus a timely reminder would possibly suffice. Several year nine students were leaving it fairly late to make a start in some subject areas.
- (2) A few students were recorded as repeating units despite having achieved satisfactory grades in the same unit (one student was recorded as having achieved a very high result in the same unit three times). In most cases the students had in fact been working at an advanced level in informal multi-level classes but had only been credited with the class rather than individual level.
- (3) Some students had been placed in formal multi-level classes and had their results recorded against the class nomenclature rather than the student's unit level.
- (4) Some students were recorded in non-existent units.
- (5) A few students had not received credits for subjects undertaken in other secondary schools.

The blind evaluation also revealed two programming problems when using the toolkit KES:

- (1) the program could not accommodate duplicate data (for example, repeated units). In this situation the program alerted users to this situation prior to continuing with the processing *sans* the duplicated data.
- (2) The program could not accommodate unexpected data (such as non-existent units). In this situation the program provided an error message then continued to the next subject area without providing any recommendations for the problem subject area.

Student Number	Year	Curriculum problems	Data problems	KES problems
4	10	PE minimum at risk		
8	8	EN Level 1 unit without prerequisites		
9	9	CO unit without prerequisite		
12	10	SA unit without prerequisite TS unit done three times although B grade each time EN extension unit but missing compulsory unit PE extension unit but missing compulsory unit SC unit without prerequisite DR - MS minimum at risk		Repeated SA unit TS unit repeated twice Repeated AR unit
13	9	SC extension unit but missing compulsory unit		
14	8	EN remedial unit without prerequisite but having failed intro unit twice is unusual case	Unknown SC unit	
15	10	AR extension units but missing compulsory units		
16	9	PE extension unit but missing compulsory unit		
17	9	DR unit without prerequisite MA unit repeated though passed	Unknown SC unit	
18	10	CO unit without prerequisite DR - MS minimum at risk	Unknown MA unit Unknown LOTE unit	
19	9		Two unknown MA units	Repeated SC unit
21	10	SC unit without prerequisites SC unit repeated though passed		

		LOTE minimum at risk TS minimum at risk	
22	9	SC extension unit but missing compulsory unit	
23	10	LOTE minimum at risk TS unit repeated though passed	
24	10	AR minimum at risk DR - MS minimum at risk PE minimum at risk SC extension unit but missing compulsory unit	
26	10	EN prerequisites skipped despite low grades PE compulsory unit skipped SA minimum at risk SC minimum at risk	
27	10	DR unit repeated though B grade Three SC units repeated TS unit repeated though B grade	DR unit repeated TS unit repeated
30	8	EN Level 2 unit placement but student is higher level	
31	10	AR extension units but missing one compulsory units AR unit repeated though A grade DR extension units without prerequisite LOTE minimum at risk PE extension units but missing one compulsory unit	
32	9	MA unit repeated though B grade	
34	9		Special Unit student
37	8	EN remedial unit before compulsory unit SC remedial unit before introductory unit	

39	10	SA minimum at risk	SC unit repeated
42	10	AR unit repeated though A grade DR - MS minimum at risk	AR unit repeated
43	9	LOTE unit repeated though C grade	LOTE unit repeated
46	10	Four SC units failed and repeated AR mimum at risk	Four SC units repeated AR unit repeated
47	9	PE minimum at risk	
48	8	Extension AR but no introduction unit	
49	9	DR unit at higher level than prerequisites	
50	8	MA unit repeating rather than sideways extension	



Table 6.2.3 records data for 275 units rather than an anticipated 300 units (50 students x 6 units), the discrepancy arising from the year ten students for whom no mathematics recommendations were made and several other students for whom only five units were listed in the school records, or instances where a student is doing more than one unit from a faculty.

Table 6.2.3 shows that more than half the unit placements were the same as single or double recommendations made by RUS; that is, 92 (33%) of student placements were the same as single subject recommendations and 53 (19%) of student placements were one or both of two subject recommendations. Most subject areas had three or fewer recommendations which accounted for two-thirds of the actual unit placements.

The table also records that students were enrolled in twenty-three units that were not recommended by RUS. Further examination revealed that the twenty-three discrepancies were outside established procedures and were not errors by RUS.

- \* Two students (numbers 9 and 18 in tables 6.2.1 and 6.2.2) were placed in advanced Computing (CO) units without completing the prerequisite unit.
- \* One student (number 17) was placed in an advanced Drama (DR) unit without completing the compulsory prerequisite unit, and another student (number 49) having already skipped a Stage continued at the higher level of Drama.
- \* Five students ( 8, 14, 30, 31, 39) had been placed in English (EN) units at a level which did not comply with the normal consequences of their previous grades. One student (37) with borderline English grades had been placed in a remedial unit. Another student (12) had been placed in an English extension unit before completing the compulsory units.
- \* One student (17) repeated a Mathematics unit instead of undertaking a remedial unit.
- \* Two students (26, 35) had been placed in Physical Education extension units without having completed the compulsory units.
- \* Two students (36, 45) were placed in Social Education Stage Three units though entitled to proceed to Stage Four. One student (49) was placed in a Stage Three Social Education unit without undertaken all four Stage Two units.
- \* One student (37) repeated a failed Science unit while another (21) was placed in a Science extension unit without completing the compulsory units. Three students (13, 22, 24) continued with extension Science units despite not having completed the compulsory units.



These exceptions to established procedures were the outcome of human error or pedagogic intervention when the students were placed in units; the individual reasons do not really matter for this analysis. However, these variations do highlight the importance of an expert system providing a decision *support* system rather than a decision *making* system, and thus allowing pedagogic judgements to intervene when appropriate. They also highlight the importance of providing a more accurate system for detecting discrepancies.

Table 6.2.4 summarises the subject area priority ratings made by RUS and compares these with the actual subject areas undertaken by the students.

*Table 6.2.4  
RUS recommendations for compulsory subjects undertaken by students*

	RUS priority		
	Urgent & Compulsory	Important & Compulsory	Compulsory
Faculty	Number of students matching the priorities recommended by RUS		
AR	4	7	1
BE	2		
CO			
DR			7
EN	48	1	
HE			3
LOTE	9	4	2
MA	32		
MS	1		4
PE	23	4	
SA	26	12	
SC	20	15	2
TS			5
Total 232	165	43	24

Eighty-four percent (232 of 275) of the sample enrolments were in compulsory units. This figure is slightly higher than the pattern that one might expect from the certification requirements which only require 78 percent (56 of 72) of each student's units from within the compulsory group leaving 22 percent (16 of 72) for remediation, extension and specialisation. The sample data does however refer to third term and it may be reasonably expected that more students will move into extension units towards the end of the year.

The data in Table 6.2.5 appears to contradict the above analysis of Table 6.2.4. Although the sample group's current enrolment in compulsory units is higher than certification requirements, Table 6.2.5 shows 171 recommendations for compulsory units that are not reflected in the sample group's current enrolment. This indicates that

a significant number of students have been undertaking extension units before completing their compulsory units and, unless prudent, they face the prospect of running out of time to comply with certification requirements. This dilemma highlights the benefit of and need for a system which monitors the overall situation.

*Table 6.2.5  
RUS recommendations for compulsory subjects not undertaken by students*

	RUS priority		
	Urgent & Compulsory	Important & Compulsory	Compulsory
Faculty	Number of students not matching the priorities recommended by RUS		
AR	2	16	8
BE	16		
CO			
DR	7	4	19
EN			
HE		1	14
LOTE	11	10	5
MA			
MS	5		21
PE	9	5	
SA			
SC	1	4	
TS	1		17
Total 171	52	35	84

### 6.3 USER RESPONSE

A further evaluation involving 25 users (11 students, 5 parents, and 9 teachers) was conducted at the end of third term 1993 to elicit user attitudes to the RUS system. This was done at the time when students were going through the normal unit selection process for the following term. These people were asked to use the RUS system and complete a survey form which had provision for responses to a five point Likert type scale and an open ended question. The questionnaire forms are shown in the following figures.

*Figure 6.3.2*  
*Student user survey*

**Recommending Unit Selection - RUS**  
**Student opinions**

Dear Student,

As you are aware, students at Dripstone enrol in six units each term; and that each term selections are made for the following term. The units selected each term, from the many possibilities, will depend on several things. For some students, selecting the next term's units is relatively easy; but for some students the process is quite difficult.

To try and make the process easier, a new computer program has been developed to Recommend Unit Selection (the program is called RUS). The aim of the program is to recommend units for next term. RUS sorts through all the units available, ignores those the student cannot select, makes sure that the student does the correct units for the year ten certificate, and sometimes asks the user questions. RUS does not do the actual subject selection, but it does print a list of all the correct units from which people can make the right unit selection.

We are asking for your help by using the computer program and telling us what you think about it!

The program is only a demonstration model to see if the idea is useful for students, parents and teachers. Because it is a demonstration model, and is not connected to the school's main computer, RUS is not as flash as a finished computer program should be. Thus we are not asking you about the presentation, but whether you think RUS would be useful and worth finishing properly.

Thanking you,

**To complete this survey, please circle the answer which best suits you.**

1. Are you a student in

Year 8   Year 9   Year 10

\*   \*   \*

2. Please respond to the following statements as they apply to you.

	Always	Most-times	Some-times	Hardly ever	Never
I know how to select units for next term	A	M	S	H	N
Selecting units is an easy process	A	M	S	H	N
My actual units this term are those I selected	A	M	S	H	N
I am unsure what units to do next term	A	M	S	H	N
I understand about compulsory units	A	M	S	H	N
RUS was quicker than selecting units myself	A	M	S	H	N
Selecting units is difficult	A	M	S	H	N
RUS was easier than selecting units myself	A	M	S	H	N
I know about extension units	A	M	S	H	N
RUS showed me extension units I could do	A	M	S	H	N
RUS made suggestions I hadn't considered	A	M	S	H	N
I need help to select units for next term	A	M	S	H	N
RUS was harder than selecting units myself	A	M	S	H	N
RUS made suggestions I had thought of	A	M	S	H	N
RUS made sure I did compulsory units	A	M	S	H	N
I would like to use RUS in future	A	M	S	H	N

You are invited to make any further comments.

*Figure 6.3.2*  
*Parent user survey*

**Recommending Unit Selection - RUS**  
**Parent opinions**

Dear Parent,

As you are aware, students at Dripstone enrol in six units each term; and that each term selections are made for the following term. The units selected each term, from the many possibilities, will depend on several things. For some students, selecting the next term's units is relatively easy; but for some students the process is quite difficult.

To try and make the process easier, a new computer program has been developed to Recommend Unit Selection (the program is called RUS). The aim of the program is to recommend units for next term. RUS sorts through all the units available, ignores those the student cannot select, makes sure that the student does the correct units for the year ten certificate, and sometimes asks the user questions. RUS does not do the actual subject selection, but it does print a list of all the correct units from which people can make the right unit selection.

We are asking for your help by using the computer program and telling us what you think about it!

The program is only a demonstration model to see if the idea is useful for students, parents and teachers. Because it is a demonstration model, and is not connected to the school's main computer, RUS is not as flash as a finished computer program should be. Thus we are not asking you about the presentation, but whether you think RUS would be useful and worth finishing properly.

Thanking you,

**To complete this survey, please circle the letter which best suits you.**

1. Do you have a student in  
     Year 8   Year 9   Year 10  
           \*       \*       \*

3. Please respond to the following statements as they apply to you, a parent, involved in selecting units for your child.

	Always	Most- times	Some- times	Hardly ever	Never
I know how to select units for next term	A	M	S	H	N
RUS made suggestions I had thought of	A	M	S	H	N
Selecting units is an easy process	A	M	S	H	N
RUS was easier than selecting units myself	A	M	S	H	N
RUS made suggestions I hadn't considered	A	M	S	H	N
I do understand about compulsory units	A	M	S	H	N
RUS made sure my child did compulsory units	A	M	S	H	N
I need help to select units for next term	A	M	S	H	N
I think RUS would be useful for parents	A	M	S	H	N
I would like to use RUS in future	A	M	S	H	N

You are invited to make any further comments:

*Figure 6.3.3*  
*Teacher user survey*

**Recommending Unit Selection - RUS**

Dear Teacher,

As you are aware, students at Dripstone enrol in six units each term; and that each term selections are made for the following term. The units selected each term, from the many possibilities, will depend on several things. For some students, selecting the next term's units is relatively easy; but for some students the process is quite difficult.

To try and make the process easier, a new computer program has been developed to Recommend Unit Selection (the program is called RUS). The aim of the program is to recommend units for next term. RUS sorts through all the units available, ignores those the student cannot select, makes sure that the student does the correct units for the year ten certificate, and sometimes asks the user questions. RUS does not do the actual subject selection, but it does print a list of all the correct units from which people can make the right unit selection.

We are asking for your help by using the computer program and telling us what you think about it!

The program is only a demonstration model to see if the idea is useful for students, parents and teachers. Because it is a demonstration model, and is not connected to the school's main computer, RUS is not as flash as a finished computer program should be. Thus we are not asking you about the presentation, but whether you think RUS would be useful and worth finishing properly.

Thanking you,

**To complete this survey, please circle the letter which best suits you.**  
Please respond to the following statements as they apply to you.

	Always	Most-times	Some-times	Hardly ever	Never
<b>A. In your role as a Subject Teacher</b>					
Recommending units is an easy process	A	M	S	H	N
RUS was easier than advising units myself	A	M	S	H	N
My advice is different from RUS	A	M	S	H	N
RUS was quicker than advising units myself	A	M	S	H	N
I do understand about compulsory units	A	M	S	H	N
RUS made sure I advised compulsory units	A	M	S	H	N
I know about extension units	A	M	S	H	N
RUS made suggestions I hadn't considered	A	M	S	H	N
I would like to use RUS	A	M	S	H	N
<b>B. In your role as a Homeroom Teacher</b>					
Recommending units across faculties is difficult	A	M	S	H	N
RUS was easier than advising units myself	A	M	S	H	N
RUS made suggestions I hadn't considered	A	M	S	H	N
RUS was harder than advising units myself	A	M	S	H	N
I do understand about compulsory units	A	M	S	H	N
RUS made sure I advised compulsory units	A	M	S	H	N
RUS showed me extension units to advise	A	M	S	H	N
I would probably use RUS if it was available	A	M	S	H	N
<b>C. Students and parents</b>					
Students have problems selecting units	A	M	S	H	N
RUS would probably be useful for students	A	M	S	H	N
Parents understand the unit selection process	A	M	S	H	N
RUS would probably be useful for parents	A	M	S	H	N

You are invited to make any further comments:

The following tables summarise the responses to the survey form by eleven students, five parents and nine teachers.

*Table 6.3.4  
Year 8 Student user response*

	Response frequencies				
	Always	Most- times	Some- times	Hardly ever	Never
I know how to select units for next term	3	2			
Selecting units is an easy process	1	2	2		
My actual units this term are those I selected		1	3	1	
I am unsure what units to do next term			3	1	1
I understand about compulsory units	5				
RUS was quicker than selecting units myself	4		1		
Selecting units is difficult		1	2		2
RUS was easier than selecting units myself	3		2		
I know about extension units	2	1	1	1	
RUS showed me extension units I could do	2		2	1	
RUS made suggestions I hadn't considered	2	1	1	1	
I need help to select units for next term		2		1	2
RUS was harder than selecting units myself				2	3
RUS made suggestions I had thought of		2	2	1	
RUS made sure I did compulsory units	4		1		
I would like to use RUS in future	5				

You are invited to make any further comments:

*RUS was very helpful and quick*

*RUS is good and quick*

*I am going to follow most of RUS's suggestions with exception of maths as I may do an extension*

*Table 6.3.5*  
*Year 9 Student user response*

	Response frequencies				
	Always	Most- times	Some- times	Hardly ever	Never
I know how to select units for next term	1	2			
Selecting units is an easy process		3			
My actual units this term are those I selected		2	1		
I am unsure what units to do next term			1	2	
I understand about compulsory units	2	1			
RUS was quicker than selecting units myself	3				
Selecting units is difficult			1	1	1
RUS was easier than selecting units myself	2	1			
I know about extension units	3				
RUS showed me extension units I could do	2	1			
RUS made suggestions I hadn't considered	1	2			
I need help to select units for next term			1	1	1
RUS was harder than selecting units myself					3
RUS made suggestions I had thought of			1	2	
RUS made sure I did compulsory units	2	1			
I would like to use RUS in future	3				

You are invited to make any further comments:

*no written comments were made*

*Table 6.3.6*  
*Year 10 Student user response*

	Response frequencies				
	Always	Most- times	Some- times	Hardly ever	Never
I know how to select units for next term	1	2			
Selecting units is an easy process	1	2			
My actual units this term are those I selected			3		
I am unsure what units to do next term		1			2
I understand about compulsory units	2	1			
RUS was quicker than selecting units myself	1	1	1		
Selecting units is difficult				1	2
RUS was easier than selecting units myself		1	1	1	
I know about extension units	1	1	1		
RUS showed me extension units I could do	2				1
RUS made suggestions I hadn't considered	1	1		1	
I need help to select units for next term		1	1		1
RUS was harder than selecting units myself				1	2
RUS made suggestions I had thought of	1	1			1
RUS made sure I did compulsory units	1	1			1
I would like to use RUS in future	1		1		1

You are invited to make any further comments:

*no written comments were made*



*Table 6.3.7  
Combined Student user response*

	Response frequencies				
	Always	Most- times	Some- times	Hardly ever	Never
I know how to select units for next term	5	6			
Selecting units is an easy process	2	7	2		
My actual units this term are those I selected		3	7	1	
I am unsure what units to do next term		1	4	3	3
I understand about compulsory units	9	2			
RUS was quicker than selecting units myself	8	1	2		
Selecting units is difficult		1	3	2	5
RUS was easier than selecting units myself	5	2	3	1	
I know about extension units	6	2	2	1	
RUS showed me extension units I could do	6	1	2	1	1
RUS made suggestions I hadn't considered	4	4	1	2	
I need help to select units for next term		3	2	2	4
RUS was harder than selecting units myself				3	8
RUS made suggestions I had thought of	1	3	3	3	1
RUS made sure I did compulsory units	7	2	1		1
I would like to use RUS in future	9		1		1

*Table 6.3.8*  
*Parent user response*

1.	Do you have a student in		
	Year 8	Year 9	Year 10
	3	1	1

	Response frequencies			
	Always	Most- times	Some- times	Hardly Never ever
I know how to select units for next term		2	2	1
RUS made suggestions I had thought of			4	1
Selecting units is an easy process		1	1	3
RUS was easier than selecting units myself	1	3	1	
RUS made suggestions I hadn't considered			4	1
I do understand about compulsory units		5		
RUS made sure my child did compulsory units	3	2		
I need help to select units for next term			5	
I think RUS would be useful for parents	2	3		
I would like to use RUS in future	3	2		

You are invited to make any further comments:

*no written comments were made*

*Table 6.3.9*  
*Teacher user response*

	Response frequencies				
	Always	Most- times	Some- times	Hardly ever	Never
<b>A. In your role as a Subject Teacher</b>					
Recommending units is an easy process	3	1		5	
RUS was easier than advising units myself	2	6			1
My advice is different from RUS			5	4	
RUS was quicker than advising units myself	2	2	2		1
I do understand about compulsory units	5	4			
RUS made sure I advised compulsory units	8	1			
I know about extension units	5	3	1		
RUS made suggestions I hadn't considered	1	1	5	1	1
I would like to use RUS	4	4	1		
<b>B. In your role as a Homeroom Teacher</b>					
Recommending units across faculties is difficult		5	3		1
RUS was easier than advising units myself	3	4			1
RUS made suggestions I hadn't considered		6	2		1
RUS was harder than advising units myself				5	4
I do understand about compulsory units	3	5		1	
RUS made sure I advised compulsory units	6	2			
RUS showed me extension units to advise	6	1			
I would probably use RUS if it was available	5	4			
<b>C. Students and parents</b>					
Students have problems selecting units	1	6	2		
RUS would probably be useful for students	3	6			
Parents understand the unit selection process		1	7	1	
RUS would probably be useful for parents	4	5			

*I would see this as being a valuable tool in unit selection, removing subjective decisions and values of teachers and students.*

*Offers 'limited' but relevant subject choices to students.*

*It gives an accurate overview of students interests AND other subject needs.*

*I'd use the system particularly for students who have difficulty understanding the selection process.*

*Seems a very good idea to prevent 'missed' subjects.*

*Overcomes lazy homeroom teachers.*

*Allows parents to understand choices available and be more directly involved in the process.*

In general, the students indicated that they knew how to select units and that *selecting units is an easy process*, though the year eight students were more likely to also respond that *selecting units is difficult*. All the students surveyed expressed confidence in their knowledge and ability to select units, though some were *unsure what units to do next term* and many *need help to select units for next term*. Although most of the students claimed to *know about extension units*, most also responded that *RUS made suggestions [they] hadn't considered*. All the students noted that using RUS was quicker than selecting units themselves and most stated that RUS was easier than selecting units themselves. Other than one year ten student, all indicated that they would like to use RUS in future. This student stated that as she anticipated leaving school at year's end there would be no need to use RUS in future!

Responses in the small parent survey suggested that although parents understood the general philosophy of a vertical timetable and unitised curriculum, they were less sure of the mechanics. The parents surveyed all indicated the need for some help in selecting units, and thought that *RUS would be useful for parents and would like to use RUS in future*.

The staff surveyed included a teacher new to the school, classroom teachers, faculty co-ordinators, two of the unit selection co-ordinators and the (Acting) Assistant Principal responsible for unit selection. The staff survey was divided into three areas: (1) in their role as a subject teacher, (2) in their role as a Homeroom teacher or student co-ordinator, and (3) their perceptions of students and parents.

It was interesting to find that most of the staff surveyed did not find recommending units in their subject area an easy process and that they indicated RUS was both quicker and easier. Half of the teachers noted that their advice was sometimes different from RUS, but that this was mainly because *RUS made suggestions [they] hadn't considered*. It should be noted that during construction of the expert system some English faculty teachers expressed reservations about an automated system that would place students in classes. These doubts were not expressed during the evaluation of the RUS system, presumably when it was seen that RUS only recommended units rather than classes.

Other than the Assistant Principal, all the staff surveyed expressed difficulty in recommending unit selection outside their own teaching field and reported that RUS (1) ensured that compulsory requirements were advised, (2) drew attention to appropriate extension units, and (3) overall made suggestions that they hadn't considered. All the

staff, including the Assistant Principal, indicated they *would probably use RUS if it was available*.

The staff indicated that they felt students did have problems selecting units and that parents did not have a clear understanding of the selection process; and thus RUS would probably be useful for students and staff. Staff made a range of written comments which reflected the aims of RUS:

*Offers limited but relevant subject choices to students.*

*It gives an accurate overview of students interests AND other subject needs.*

*I would see this as being a valuable tool in unit selection, removing subjective decisions and values of teachers and students.*

*Overcomes lazy Homeroom teachers.*

*Allows parents to understand choices available and be more directly involved in the process.*

#### 6.4 CONCLUSION

The RUS system was formally evaluated using (1) blind tests to compare the expert system's recommendations with actual outcomes, and (2) inviting end-users to trial the expert system, complete a questionnaire and discuss their impressions of the expert system and its potential usefulness.

The two formal evaluations indicated that the RUS system provided accurate recommendations for students except in subjects with data problems (repeated or unknown units). Certainly the performance of the expert system appears to be an improvement over the current manual system, as evidenced by the number of current system problems revealed for a significant number of students. The sample size was considered sufficiently large to evaluate the system and to highlight the problems that exist for many mainstream students. It would appear that the hidden majority need more assistance in subject selection than was previously considered. At the same time, however, it is recognised that the student data was for units actually undertaken and least some of these might not reflect student selections. However, the result is the same — a number of students whose academic progress does not conform to established procedures.

The RUS system was less successful in making recommendations for students who experienced significant learning difficulties (as evidenced by many subject failures, repeated units, withdrawn units, a high proportion of remedial units, or members of the school's Special Unit). Advising these students is normally done on a one-to-one basis and there is probably less need for a decision support system in this process. This is not to suggest that an expert system could not be developed to provide a decision support system for these students; rather it is a recognition that the RUS system was not prepared for these students and thus was of limited success in this area.

There was a positive response to the concept of computerised decision support systems in general and overwhelming support for the RUS system to recommend unit selection. Perhaps as a reflection on the current manual system, many of the survey group suggested making the RUS system available even in its current form. Neither the students nor the parents were daunted by using and receiving advice from a computer. None of the staff expressed negative concerns regarding the potential impact on their work or status; indeed, all concerned stated positive benefits for themselves and the students.

## Chapter 7

### FINDINGS AND RECOMMENDATIONS

#### 7.1 INTRODUCTION

The research reported in this thesis was undertaken to explore the development of an expert system for use in educational administration. A review of the available literature indicated that expert systems might be developed to provide effective decision support systems to be used in schools. The research endeavoured to do so, and also examined whether the development of an expert system could be done by the school rather than for the school.

One of the most important administrative responsibilities of schools is to ensure that students undertake studies that comply with certification requirements. Schools with a unitised curriculum and a vertical timetable have a very complex task to ensure such compliance. The survey school sought to address this problem by developing formal paper models. The research reported in this thesis aimed to replicate and extend these models by a computerised decision support system.

Formal models were developed to extract and simplify the key features of the domain. This initially involved translating the mental models of the school personnel. These translations were mediated and consolidated in a series of descriptive, prescriptive and normative models which were then used as the foundation for constructing the expert system.

The RUS system was developed using a commercial toolkit which had been released in 1989. Recommendations made by the RUS system were evaluated against the current system. Evaluation of the RUS system also included user validation.

## **7.2 FINDINGS**

The primary aim of this research was to design and implement a computerised expert system to assist a specific decision making domain in a school. The RUS system was demonstrably successful and clearly indicates the potential for the administration of schools to be assisted through the use of expert systems. Whereas the current school procedures provided a range of data the RUS system provided decision makers with a range of reliable options. Further, an examination of the potential time saved with the RUS system enhances the benefit of this expert system to school administration.

In addition to the main aim, one objective of this research was to explore whether an expert system could be prepared by school staff. The success of the RUS system which was prepared by the school principal with assistance from the school staff supports this potential scenario. Though not formally evaluated, it is considered that this research confirmed the benefits of involving all the school personnel in such projects, especially in analysing current procedures and actively participating in the construction of models. Other objectives associated with the design and implementation of the expert system were found to be important components of the overall success of the expert system. The expert system did provide a facility to encapsulate the expertise of leaders in the specific domain and make it available to guide others through an effective set of interacting rules which could be used by a computerised decision support system.

### **7.2.1 EVALUATION OF THE RUS SYSTEM**

A pivotal assertion is that current manual systems involving human experts do not provide sufficient or ready access to their expertise and that manual systems are prone to errors. The research was intended to demonstrate that computerised decision support systems can reduce these problems.

The performance of the prototype expert system clearly demonstrated the validity of its recommendations which, in general terms, exceeded the current manual system supplemented by human experts. The evaluation reported in Chapter Six highlighted the reliability of the prototype's recommendations and the lack of errors by the RUS system. User responses were positive, despite the unsophisticated presentation of the RUS system, and supported the introduction of an expert system in this domain.



The evaluations reported favourably on the RUS system but it is important to stress the role of expert systems as a decision support system. Although the evaluations indicated that the current manual system had placed some students in classes outside the normal pattern, and which would not have been recommended by the RUS system, some of these were the result of pedagogic decisions rather than errors. On the other hand, the number of errors associated with the manual system also highlighted the need for an improved technique to detect problems before it is too late, a process which the RUS system did very effectively.

### 7.2.2 TIME

The current unit selection process is concentrated over a four week period at the end of each term. Each student is given a copy of the school records showing their units completed and currently studied. The students, following consultation with the curriculum handbook, teachers and parents, complete a form indicating their unit preferences for the following term. The unit request forms are initially scrutinised by homeroom teachers and then examined in detail by a team of four co-ordinators. The co-ordinator's task is to ensure that the unit requests comply with certification requirements, faculty and school procedures. The co-ordinators also follow up with the few students whose requests can not be accommodated by the resulting timetable. The four co-ordinators usually spent two weeks and the intervening weekend on these tasks.

A series of trials with twenty-five first-time users took nearly half an hour for each person to use the RUS system. However, it could reasonably be expected that future individual use would be approximately fifteen minutes when people were familiar with the program and/or did not have complicated unit selections. Two of the co-ordinators were included in the trial and were distressed to discover that, despite their best endeavours and the significant time spent maintaining the current system, some students had still not complied with all the requirements. Both co-ordinators expressed optimism that the RUS system could significantly reduce their workload checking student preferences and suggested that students using the RUS system attach the expert system's recommendations to their unit selection form enabling the co-ordinators to automatically process the student's selected units if they were based on these recommendations.

The research reported in this thesis was conducted over several years including nine months full-time preparing the RUS system. In light of this experience, it is

suggested that for a school with adequate resources and determination to conduct a similar project it would take approximately eighteen months and require the following process:

- (1) school to determine a possible domain and appoint a consultant as project manager,
- (2) preparation of formal models by the school,
- (3) translation of formal models to computer models by knowledge engineer,
- (4) evaluation of computer models by school,
- (5) use of technicians to prepare the user interface and program output, and
- (6) evaluation and maintenance of the resulting program.

The selection of a project manager, knowledge engineer and technician would depend on local factors. But the key element is that these people would be working with and for the school, and that their role would be responding to and accommodating the school's input.

On balance, the time invested in developing the RUS system would have a relatively short repayment period, even allowing for the additional time needed to get the RUS system to a marketable stage with full documentation etc. This estimate does not take into account the financial cost of purchasing the necessary computer hardware and software; but neither does it take into account the benefits of reliable recommendations for students, parents and staff at the school.

### **7.2.3 SCHOOL INVOLVEMENT**

Kraft (1985, 48) stated that "developments must be user driven" rather than "foisted off" on the end-users. This view is supported by other studies (for example, O'Connor and Tirello, 1969, Adair, 1984, Sirotnik and Burstein, 1987) which have demonstrated the benefits that accrue to organisations where changes have been carefully introduced and, in particular, where the people concerned have a sense of ownership in the new technology. Most computer systems in Northern Territory schools have been developed by people outside the schools. Despite some attempts to involve school personnel in the development of these programs, such development has rarely been under the control of the school and inevitably school procedures have been modified to satisfy the computer program's requirements (Bucknall 1988).

The Principal's role as knowledge engineer had a number of benefits. The day-to-day responsibility for curriculum matters was one of the duties of an Assistant Principal and the Principal's role during the review and development process enabled the Principal to gain a better understanding of curriculum implementation details. On

the other hand, as a member of the Northern Territory Board of Studies, which determines overall curriculum and assessment policies, the Principal was able to ensure that the resulting models conformed to official guidelines. The researcher, as Principal and knowledge engineer, was in a position to be critically involved in the development of a support system that was needed and likely to be used by the school. Although the benefits of staff participation were not formally evaluated, such participation is considered by the researcher to have contributed to the overall success of the project.

The involvement of the school's personnel in this project was considered to be a significant benefit to the school, especially in the formulation of the formal models and the pedagogic component of developing the RUS system. There were indirect benefits to teachers and the school's administration that accrued through the clarification of ideas previously presumed or taken for granted, the increased awareness of organisational structures, and the heightened discussion about their knowledge and reasoning. The human experts were encouraged to disassemble their thoughts and experiences. Thus, in a small way at least, the richness of this expertise was shared with other staff when developing the school handbooks, and was shared with the wider school community through the school handbooks and through demonstrations of the RUS system. In a wider sense, the potential Hawthorne effect was considered a benefit for the project's status.

#### **7.2.4 KNOWLEDGE ENCAPSULATION**

The trial school was regularly faced with the need for subject selection decisions based on the expert knowledge of individuals. The quality of the expertise available in the school varied despite attempts, such as documenting the expert's knowledge in the school's handbooks, to encapsulate the expert knowledge. However, and despite these endeavours, recommending subject selection inevitably resulted in some decisions being made by people who were less than expert. The comparison between recommendations made by the RUS system and the current manual system also highlighted the potential ramifications of undetected errors in the current system and thus the need for an improved method to advise and track student progress towards their Junior Secondary Studies Certificate.

The RUS system was successful in encapsulating the expertise and making it available to others. In response to the concerns expressed in Chapter Two (section 2.6.1) whether a computer can and should replace people, it is important to note that this prototype expert system was designed to support rather than replace human decision making. The technical components of the expert system, such as the

inference engine, are beyond the understanding and control of most people; but the knowledge encapsulated in the faculty systems was easily understood by the human experts and could be easily modified by the school staff. The RUS system was deemed by the human experts to be successful in freeing them of the chore of processing large amounts of complex information and enabling them to be better employed dealing with exceptions rather than the norm. The client group composition will help to ensure that knowledge encapsulated in the system will be monitored and challenged, especially if recommendations differ from the information available from other sources.

#### **7.2.5 KNOWLEDGE REPRESENTATION**

The research design was intended also to examine (1) whether the body of knowledge held by the subject experts could be represented by a set of rules, and (2) whether someone outside the faculty domain could use these rules to prepare meaningful recommendations.

The school's published formal models were used as the foundation for constructing the expert system in which production rules were used to represent the knowledge base. Unisys recommended a rule-based inference engine for the selected domain, in preference to the Hypothesise and Test or Bayes inference engines, which used frames and statistics respectively. The school personnel who reviewed the rules for their subject area did not express any difficulty in understanding the syntax of or relationships between the rules.

The RUS system was developed as a decision support system to be used by students, parents and teachers. It is considered that all these users had the expertise to evaluate the advice provided but that they will still benefit from using the expert system as an appropriate source of knowledge. The findings of this research do not support the notion, reported in Chapter Two, that access to expert systems should be restricted to people with appropriate training and expertise — though it could be argued that the students, parents and teachers experiences have provided them with appropriate training and expertise.

A variety of models were used to assist construction of the knowledge base. The most consistently useful models in this process of knowledge representation were (1) faculty flow-charts modified from those published by the school and (2) faculty summary models derived from analysing the flow charts and interviewing staff. The researcher had anticipated extensive use of decision tables to help ensure that appropriate factors were included in the rules and also to assist debugging contradictory

recommendations. Although useful in the development of some subject area systems, especially to clarify interpretation of unit pre-requisites, levels and stages, most attempted decision tables became too complex to be usefully documented on a two dimensional model. There were many instances where more than one set of multiple conditions would result in rules firing, thus requiring a three dimensional matrix model.

The success of the RUS system demonstrates that the body of knowledge held by the subject experts could be represented by a set of rules and that someone outside the faculty could use these rules to prepare meaningful recommendations. Further, the language of the rules used in the knowledge base helped to ensure trust in the expert system's advice. The teaching staff were able to easily proof read the faculty rules and were not distracted by the programming elements.

#### **7.2.6 TOOLKIT**

It would appear that the software development tool KES II™ was a product ahead of its time. When it was released in 1989, experienced knowledge engineers were using programming languages and/or LISP work stations while an increasing variety of shells were intended to catered for the amateur market. At that time the potential role for toolkits appears not to have made a significant impact on the market, probably because they were too complex for computer-illiterate people while programmers stayed with what they already knew. In response to an inquiry by the researcher in 1993, an employee of Unisys (unofficially) advised that KES had not been a commercial success, and was probably in use in only a few situations around the world. Despite this, the research reported in this thesis suggests that amateurs can meaningfully participate in the introduction of information technology and that a toolkit may be an appropriate software program facilitating hands-on involvement.

A significant problem arose when it was discovered that the computer hardware used by the researcher did not support all the software features; in fact, only a mainframe computer would currently support all these features. In particular, the inability to use the external feature in KES to run other programs while KES was in use was a severe limitation and prevented the use of a central (control) KES program to call the separate subject systems. As it was considered undesirable (for operational speed and future editing) to have a single KES program, a control program was developed using the computer's operating system linking a series of COBOL and KES programs. This relatively unsatisfactory situation highlighted the likely need to use technicians to finalise a marketable expert system, but does not detract from the benefits gained from using amateurs in the development process. The research supports the concept of a

balanced relationship in which the school personnel deal with the pedagogic issues and the technicians handle procedural matters.

The use of other systems to support KES also demonstrated the power of KES in that the COBOL program used to select and extract the data from student files required 316 Kilobytes of computer memory, whereas the various subject expert systems to process the millions of possibilities within the student data ranged from 8 to 30 Kilobytes of computer memory.

Despite its limitations, the toolkit KES was a key element in the success of the project in achieving the third objective — it enabled the researcher to develop an effective decision support system. The students, parents and staff who participated in the project expressed the need and desire for the RUS system to be implemented. Staff at the Department of Education's Information Systems section who had assisted the research suggested the potential for a similar expert system to monitor the subject selection of senior secondary students. Despite the success of the RUS system and encouragement by these people, the project did not proceed beyond the prototype stage because the researcher was transferred to another school, external technical assistance was needed to upgrade the RUS system to commercial standards, the Information Systems section was transferred from the Department of Education and the Department of Education commenced replacing its aging Unisys system.

### **7.3 RECOMMENDATIONS**

It is recommended that Departments of Education consider the introduction of expert systems as decision support systems to assist school councils which are dealing with increased responsibilities such as financial management. Given the turnover of council personnel, such a system would reduce the need for training programs and could help to ensure a more consistent standard of decision making.

It is recommended that the Northern Territory Department of Education consider the use of an expert system to track and recommend the subject selection for Stage One and Stage Two students (Year 11 and Year 12). The current conventional program used to track these students, while providing a valuable first step, may benefit from being upgraded to a decision support system. Given the standard nomenclature for subjects at this level, it appears feasible to develop an expert system that could be used for all senior secondary students in the Northern Territory.

It is recommended that Departments of Education develop a pool of expertise in the field of expert systems, either within their own staff or through contractual arrangements, thus to facilitate the introduction of the previous recommendations.

#### 7.4 CONCLUSION

It was perhaps naive to expect that an amateur alone could produce a commercially viable expert system. However, the research has demonstrated that a school administrator with some computer literacy was able to initiate and develop a meaningful and effective expert system with benefits to the institution arising from both its development and its use.

The RUS system appeared to most end users to be just another computer program, more so because it used the same computer hardware and some similar computer software already in use at the school. The actual coding for the expert system has a familiar appearance to some conventional computer programs, especially with the use of production rules. Thus it is appropriate to ask whether the end product really is an expert system. There are two main reasons for an affirmative answer: (1) programming technique, and (2) user interface. Despite the use of rules in the expert system, the construction and firing of these rules to provide forward and backward chaining is demonstrably different to conventional programming. The power of this can be seen in a comparison between the English faculty in the RUS system where several dozen rules accommodated more than one million potential combinations, against a conventional program (written for the Department of Education to keep track of the units students had done) in which many hundreds of rules were required to accommodate several thousand combinations. Although relatively crude in some aspects, the facility for users to ask the RUS system for an explanation of questions and justification of recommendations goes much further than could be written into conventional programs. Overall, it is reasonable to conclude that the RUS system does provide *expert advice* to users.

It is also reasonable to conclude that schools which actively participate in the development of these systems for their use have the potential to gain many benefits. Despite some attempts to involve school personnel in the development of these programs, such development has rarely been under the control of the school. Expert systems may offer schools the means to be positively involved in developing their own programs, with two significant benefits: (1) school participation in such an exercise may be an excellent review and development process, and (2) the school is likely to

obtain a product which it needs and will use. This is not to imply that developing an expert system is a simple exercise, but it is one in which the school personnel can deal with the pedagogic components and only use technicians to deal with procedural matters such as extracting required data and preparing screen layouts. Toolkits, or shells, may empower amateurs to be effectively involved in developing expert systems, especially if some training and guidance is available.

Based on the research reported in this thesis, it would take a school approximately eighteen months to develop an effective expert system if financial and technical resources were available. The project reported in this thesis took considerably longer, but much of this time was spent researching about modelling and computer systems and learning how to prepare an expert system. The appointment of a competent project leader would facilitate the formal modelling processing, knowledge elicitation and computer programming. In addition to the cost of appropriate computer hardware and software, the project budget would also need to include short periods of time-release for staff and a significantly longer period for a knowledge engineer.

The RUS system developed in this research project was demonstrably successful in the three key criteria: the recommendations were more reliable than the current manual system and human experts were providing; the staff surveyed supported its introduction as an extension rather than downgrading their professional responsibilities; and the students and parents surveyed indicated they would use the system.

The research findings support the assertion that the design and implementation of expert systems should be actively considered to provide decision support systems within various domains of educational administration.