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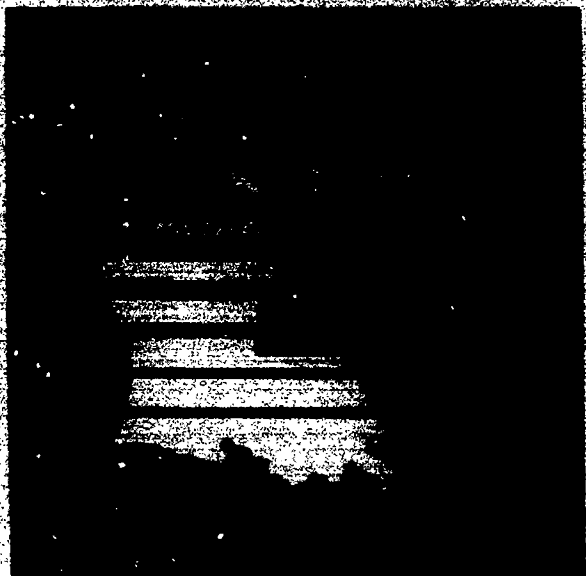
ABSTRACT

A student who plans to enter the field of technology education must be especially motivated to incorporate computer technology into the theories of learning. Evaluation prior to the learning process establishes a frame of reference for students. After preparing students with the basic concepts of resistors and the mental tools, the expert system should be introduced. Specifically, expert systems are computer programs that encode the knowledge of an expert and replay this information to the novice. An emerging area of expert systems is in education. Building expert systems in education consists of five interdependent activities: identification, conceptualization, formalization, implementation, and testing. Expert systems contain the knowledge of a well defined but narrow field. Integrating basic skills in technology education, specifically, component identification in electronics technology, fits the criterion for expert systems. An expert system works by asking an end-user a number of questions to help pinpoint a problem by narrowing down the answers. These questions are created by an expert in the specific field of resistor identification. In one project, the expert system has been developed on MicroExpert, an expert system shell produced by McGraw Hill. (Appendixes include 13 references, listing of the expert system, and reproductions of actual screens on the computer when the MicroExpert program is executed.) (YLB)

Vocational Education Research

TITLE: INTEGRATION OF BASIC SKILLS INTO VOCATIONAL EDUCATION: *EXPERT SYSTEMS IN ELECTRONICS TECHNOLOGY*



University of Southwestern Louisiana

1991

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PROJECT TITLE

INTEGRATION OF BASIC SKILLS INTO VOCATIONAL EDUCATION:

EXPERT SYSTEMS IN ELECTRONICS TECHNOLOGY

PROJECT DIRECTOR

GAMINI WEERASEKERA

Funded by
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FOREWORD

This research guide was produced as a result of a project funded by the Louisiana Department of Education to the University of Southwestern Louisiana.

Application of Computer Aided Instruction (CAI), specifically expert systems, can assist in technology education. The expert system developed in this project can be utilized in integrating basic electronics skills in technology education endeavors. The program developed has been field tested and evaluated.

Using this project as a basis for developing *real* CAI applications, educators should be able to develop expert systems to assist them in their instructional programs. Furthermore, these intelligent assistants will establish supportive learning environments for the students.

We believe that this unit on Computer Aided Instruction will make a major contribution to the improvement of technology education in the State of Louisiana.

Raymond G. Arveson
Superintendent of Education.

ACKNOWLEDGEMENTS

This publication represents the cooperative efforts of personnel of the University of Southwestern Louisiana (USL) and the Technology Education Section in the Office of Vocational Education, Louisiana Department of Education.

Prof. Gamini Weerasekera at the University of Southwestern Louisiana served as the Project Director. Mr. Wayne Fruge, Instructor, Port Barre High School, served as a special consultant. Mr. Edward Gaspard, senior student at the University assisted in the development of the expert systems.

Special recognition goes to Dr. Florent Hardy, Jr. and Mr. Jerry O'Shee of the Louisiana Department of Education. Their patience, encouragement and mentoring assistance made this project possible. A sincere ***Thank You*** goes to USL President Dr. Ray Authement; Academic Vice President Dr. Gary Marotta; Dean of Engineering Dr. Anthony Ponter; former Department Head Prof. F. Gary Amy and the present Head of Department Prof. William Mueller for their confidence and assistance on this research project.

Chris W. Strother
Assistant Superintendent
Office of Vocational Education

ABSTRACT

This research guide is the product of a research project dedicated to the integration of basic skills, expressly component identification, in electronics technology, using an expert system. The procedures utilized the MicroExpert Shell, developing an expert system for resistor identification. For evaluation of the developed expert system, the facilities of the project principal investigator and project consultant were utilized. The scenarios included actual classroom conditions to test the expert system.

Omnipresent is the increased use of computers in most aspects of present day life. Those in the field of technology education must be especially motivated to incorporate computer technology. That ecumenical assimilation is a fundamental objective of this expert system program.

There are three interlocking elements of this project. One is the learning process the student undergoes while he/she utilizes the expert system. The second element is the electronic component identification procedure. The third element is the actual programming of the expert system.

Using the expert system to teach resistor identification does not constitute a complete teaching process. It is part of a guidance and/or reinforcement strategy of instruction. Initially the basic electronic concepts of resistance, Ohm's Law, resistor materials and resistor construction should be introduced. The expert system should be utilized only after a through understanding of the fundamental concepts of electronics.

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INTRODUCTION

In electronics technology, an essential feature is component identification. Expert systems lend themselves to capturing and dissimilating knowledge. The educational process of learning component identification can be augmented via the use of the knowledge base of an expert system. This research project represents successful synthesis of basic skills, the development of an expert system for resistor identification and the appropriate application of an expert system in the classroom environment.

There are three constituents of this project. One is the learning process for the student utilizing the expert system. The second item is the resistor identification procedure. The third element is the actual interaction with the expert system.

Using the expert system to teach resistor identification should not be construed as a complete teaching process. It is part of a guidance and/or reinforcement strategy of instruction. Initially the basic concepts of resistance, Ohm's Law, resistor materials and resistor construction should be introduced. The expert system should be utilized only after a through understanding of the fundamental concepts of electronics.

LEARNING THEORY

Introduction

Computers are omnipresent and are an approbation in our lives. From the industrial work environment to transportation to the home environment, computers are sanctioned (and condoned!) Thus it has become essential for today's student to have a working knowledge of computers. A student who plans on entering the field of technology education must be especially motivated to incorporate computer technology into the theories of learning.

No computer, withstanding all the advances in hardware and software, can compete with the classroom teacher. Thus the expert system developed herein does not constitute a complete teaching process. It is more part of a guidance and/or reinforcement strategy of instruction. Only after the basic concepts of resistance, Ohm's Law, resistor materials and resistor construction have been introduced, should this particular strategy of instructional assistance be introduced.

Evaluation

Evaluation prior to the learning process is necessary because students need to establish a frame of reference in order to prepare themselves for their objectives. To do this, the instructor must first evaluate the student's knowledge of a subject.

Currently there are two methods of assessing the student knowledge base. First, there is the naturalistic approach. Utilizing the techniques of the Socratic dialog method, naturalistic evaluation of students consists of merely asking questions that encourage a group discussion of the subject. During the discussion, the instructor should observe how students react to the subject, what aspects of the subject stimulate the most interest, and with which aspects of the subject the students are most familiar.

The second type of evaluation is a standardized approach. The instructor should put together a quiz designed to evaluate the student's background knowledge of the subject. Both approaches are of great benefit to the instructor in the preparation of the lesson plans (Vacca. 1981).

There are several reasons for an evaluation of the student's background knowledge of resistors and/or expert systems programming. First, students may lack sufficient knowledge of the subject. This would be especially true for secondary school students. Second, students who have sufficient knowledge may fail to bring it to bear as they processed through the expert system and ultimately may not utilize the program to their best advantage. Third, those students who progress too rapidly through the program might overlook some of the many possibilities the program might be able to present to them for future use. (Vacca. 1981).

Metacognition

One aspect of learning that the expert system program possesses is a strong advantage to stimulate the mental ability of metacognition. Metacognition is the knowledge of learning. An alternate definition of metacognition is the ability of knowing how to learn. Two concepts of tandem importance that are within the ability of metacognition are self-knowledge and self-monitoring. Self-knowledge is the ability of recognizing what knowledge one already knows about the subject and drawing relationships from that knowledge. Emphasis on this ability to a class after covering the basic essentials of resistors and before operating the expert system will give students more confidence.

Self-monitoring is the ability to recognize what progress one has made towards an objective. This also makes it possible to recognize weaknesses and strengths. Learning logs utilize this ability to a large extent (Vacca. 1981). These concepts are essential to introduce to students who are preparing to operate an expert system. However, the responsibility of developing these abilities rests entirely upon the shoulders of the students. Certainly, how the students approach the cognition tasks determines their own success.

Learning by Doing

After preparing students with the basic concepts of resistors and the mental tools, the expert system should be introduced. This is the opportunity for the student to develop their own knowledge base on "what" and "why" of the device/characteristics. As the concepts are pulled together, the "why" or reason for the use of different component characteristics will become apparent. Students should be encouraged to identify words in the context in which they are found rather than referring to a dictionary or glossary.

The context in which a word is embedded rather than the dictionary definition is what gives it a unique flavor (Vacca 319). A student who knows more words about a subject also has more knowledge about a subject and this leads to better comprehension about a subject. Both students bound for vocational-technical careers and students of higher educational careers will benefit from this type of computer knowledge base. This is especially true in a career such as electronics where the technology is changing at a rapid pace. However, these changes will not be too fast for most modern technical institutes, colleges and universities; if they were to efficiently utilize expert system based knowledge bases.

It is reality that computers are an integral part of our lives. They are tools that can help us, especially in the field of education. Computers, however, even with all their "bells and whistles" cannot supplant the classroom teacher. Computers, expert systems and other forms of CAI can be utilized to assist the teacher in the integration of basic skills in electronics technology. Therefore, the technology is only a support facility, i.e., the expert system facilitates the learning process, as a guidance and/or reinforcement strategy of instruction.

EXPERT SYSTEMS IN EDUCATION

Expert systems are an archetype of artificial intelligence (AI). Similar to the endeavors of AI, an expert system attempts to emulate a human being's thinking. Specifically, expert systems are computer programs which encode the knowledge of an expert, and replay this information to the novice. An emerging area of expert systems is in education.

History

In the 1970's, various prototypes of computer programs were developed by the AI scientists. With limited success, these programs had the ability to emulate human thinking. AI scientists had success with narrowly defined problem solving, i.e., capture expert knowledge for a well defined problem. This was the birth of expert systems. In the 1980's the significance of AI emerged in the format of commercially applicable expert systems. Today there is a significant attempt by educational research organizations to develop expert system-based educational materials. These expert systems typically will be based on 32 bit microcomputer systems. As a result of the expert systems, the classroom teacher can address areas which require the "human touch", letting the computer meet the routine needs of the students.

Introduction to Expert Systems

The expert system manipulates knowledge bases. It will use heuristics, which is "knowing by doing" i.e., the practical experience knowledge of the expert. The expert's heuristics are encoded in the knowledge base for seeking a solution. Essentially, the expert system will limit the number of search paths, via the intelligent use of the knowledge base. Furthermore, expert systems in education will provide: satisfactory rather than optimum solutions; sometimes no answers; and gives probable responses, i.e. 70% certain this is the solution. These answers are similar to human experts who also provide probable solutions and typically provide satisfactory (rather than optimal) solutions.

Expert systems in education can be appropriate when the decisions have been made naturally via manipulation of symbols and symbolic information. Any mathematics that is necessary has to be a simple calculation. Thus if it requires a high level of mathematics, i.e. differential equations, the problem is quite possibly a candidate for conventional programming.

Building expert systems

In the development of an expert system the paramount consideration should be the heuristics approach to decision making. Expert systems, unlike conventional programs, deal with information management rather than numeric processing of conventional programming.

Building expert systems in education consists of five interdependent activities; identification, conceptualization, formalization, implementation and testing. (Buchannan. 1983).

The scope of an expert system has to be broad enough to make it a significant project, but also narrow enough to make it a plausible effort. This is a paradox; because the expert system cannot be so narrow that it does not provide any real expertise to the educator; nor so broad that it will take ten man years to build; and requiring the power of a supercomputer. In considering the broadness of the decisions, if the educator takes weeks to reach a decision, those decisions may be too complex for an expert system application. However, if it is possible that the decisions could be broken down into a series of smaller decisions, then the smaller decisions would be candidates for an expert system.

Through personal experiences, the goals set for the knowledge base of the expert system are, usually, too broad. Thus, as the project formulation progresses, the scope will be curbed! On the projects where the initial scope was too broad, when the range is narrowed, sub-areas are developed. Then it becomes possible to develop expert systems for these sub-areas. Now, collectively, the expert systems have the scope of the initial project.

There are five universally accepted truths and conditions which must be confirmed prior to building any expert system. These are:

1. There is presently human expertise to make these decisions. Their expertise is cognitive in skills. Furthermore the education experts (classroom teachers) generally agree on the provided solution to a problem.
2. The expert has formal learning on the subject, which is augmented by extensive experience in making this type of decision.
3. The expert must be able to explain to a novice the techniques used in solving the problem.
4. Realizing that the solution cannot wholly be an exercise in common sense, the problem must have parameters. Expert systems are used to solve well defined problems.
5. The problem to be solved must have significant applied value. Furthermore the problem should be able to be solved in a reasonable length of time. (Gevarter. 1985)

It is unrealistic to define a set of correct steps in building an expert system. Personal experience and the experience of other knowledge engineers has shown that having rigid parameters in the development of an expert system is impractical.

When building an expert system, a phenomenon called paradigm shift occurs (Hays-Roth. 1983). Developing the knowledge base for an expert system is an incremental technique; incremental because, one piece of information/knowledge is used in building the next item of information. As these evolutionary steps are taken, the system usually becomes cumbersome. The system will parallel dinosaurs! Paradigm shifts are likened to the human expert who may "go off in an tangent" when solving a problem! An expert system with a paradigm shift will be slow to react, and will be a hodge-podge of rules and heuristics. When a paradigm shift occurs, the complete expert system is to be reevaluated by the knowledge engineer and the teacher. Quite often this scrutiny will result in changing the tools and adopting a different knowledge classification system.

Building an Expert System: Identification

The knowledge engineer and the educator will interactively identify the significant features of the skills to be encoded. It is at this point that the initial scope of the system can be defined. Furthermore, it would be wise to evaluate at this point if, in fact, an education expert system is the most appropriate technique. At this stage, it is also necessary to identify the need for other educational experts. Case in point being for this project, the principal investigator has formal education and over twenty years of experience in electronics components; however, the project was a team effort. Along with the principal investigator, there was one consultant and one senior student for the identification process. Once the scope and significance of the project has been determined, then the resources needed to carry out the project need to be identified. Resources include computing equipment and funds for personnel.

Subsequent to the resource identification, the knowledge engineer and the educator can begin to define the education decisions which will be encoded into the expert system. The definition of the decisions will lead to the identification of the decision making techniques. The categorization of the subsections of the decisions occur at this juncture. Furthermore, the decision constraints can also be discussed at this point.

Formalization is the defining of relationships of the abstractions/theories of the conceptualization stage. A pre-requisite to this would be the knowledge engineer's selection of the expert system development program.

The knowledge engineer then writes the expert system. His or her assistance becomes formalized concepts. Further assistance can be derived from the facilities of the expert system development program, namely the comprehensive editors and trace facilities.

Using the procedures of the expert system shell, the knowledge engineer can test the expert system. He/She will be able to use the input/output facilities, the explanation and trace facilities. Often used is the "break facility" or software techniques of halting program execution at a particular location. This facility is utilized in determining the general location of an elusive but recurring rule causing an error in the conclusion.

It is imperative to have the educational experts' assistance at this juncture. The classroom teacher will be (and usually is eager to) put the expert system through its paces. Quite often the teacher will uncover major errors or omissions–typically in the fringe areas of the program knowledge base. This will necessitate the backtracking of the building process. It is not uncommon that this process will lead to re–identification and re–defining the purpose of the expert system.

Education Expert Systems Building Programs (Tools).

The use of system building tools is to assist the process of building an expert system in education. These tools are analogous to text editing tools (i.e. word processors) or accounting tools (i.e. spreadsheets).

These tools are distinct from traditional programming languages such as FORTRAN or PASCAL. Expert system tools are also different from the Artificial Intelligence (AI) programming languages i.e. LISP or PROLOG. Traditional programming languages are problem-oriented languages. Example: FORTRAN, is used for scientific and engineering applications, i.e. numeric manipulations. In comparison, the expert system tools are designed for symbol manipulation. Unlike traditional AI languages, expert system development tools provide a host of features which contributes to an easy to use environment.

Knowledge engineering tools (expert system development shells) are essentially expert systems void of the domain specific knowledge. Two well known knowledge engineering languages are KAS and EMYCIN. PROSPECTOR (Geology) without its knowledge base is KAS. EMYCIN combined with a domain specific medical knowledge base is MYCIN. Many knowledge engineering languages have extensive support facilities which are: Comprehensive editors; Input/Output facilities; Explanation facilities; and Trace facilities.

Editors are programs which ease the entry of information into the expert system. Quite often these are "word processor" type environments. These editors may have the sophistication of keeping a running account of the rule entry date and person. Most editors have a syntax checking ability. These not only detect incorrect grammar but also are capable of suggesting corrections. One useful feature of editors (which is sometimes available) is a semantic checker. This is a valuable aid to check if the current rule conflicts with the knowledge base.

Input/output facilities are a significant facet of the tool. One expert system designed at the University of Southwestern Louisiana has a data acquisition and process control system interfaced with an expert system. (Weerasekera. 1988) This system accepts data from an (model) assembly line. The data are then fed to the expert system which evaluates the information. Next, the expert system will provide a control signal. This signal is used by the assembly line to control a process. Because the system is "looking, evaluating, adjusting/controlling" simultaneously, this is real-time adaptive control.

Explanation facilities in the expert system tools provide the user with a descriptive response to a query. These are used for explaining why it is asking the user a particular question. Furthermore, the explanation facility can define how it reached a particular conclusion. This is a significant feature in an educational expert system. A student will be able to ask why the expert system is asking a particular question. Please see Appendix B for an interactive session on this feature.

explain the logic followed by the program. Furthermore, this is the logic followed by the human expert, i.e. the teacher! This will significantly assist the student in following the logical train of thought of the teacher in integrating basic skills for component identification electronics.

Trace facilities are primary aids in debugging. Using the trace facilities one can follow the sequence of rules fired during a session with the expert system. Certain expert systems also contain a break facility. Incorporating a break, the system would halt at a particular rule. This technique can be used to determine the location of an elusive but recurring incorrect rule.

Currently there are a multitude of expert system development tools on the market. This availability will mushroom in the coming years. Unfortunately, there are no IBMs, WordPerfects, or Lotus 1-2-3 type standards in the expert system tool market. For the system developer, matching the problem to the right tools is a crucial and perilous decision! According to Waterman there are six fundamental questions to be addressed when evaluating tools:

1. Does the tool provide the power and sophistication needed?
2. Are the support facilities adequate?
3. Is it reliable and is it being maintained?
4. Does the tool have the features to meet the needs of the decision?
5. Does it have the features needed by the solution? (Waterman. 1986)

While a programming language (PROLOG or LISP) will provide the greatest power and flexibility, they are also the hardest to use. A tool, in comparison, will limit the adaptability but will greatly ease the effort of developing an expert system in education.

The tool's extensive support facilities will ease the effort of developing and executing the program. Excellent text processing, syntax and grammar checking will ease the effort. Debugging and trace features will assist in the trouble-shooting of the program.

Reliability is of significant value to the knowledge engineer and the educator. An unreliable system will not only frustrate the knowledge engineer, it will effectively negate any benefits to the educational effort. Reliability could be evaluated by the tool having a large user community. Furthermore a tool has to be actively supported by its manufacturer. If maintenance of the tool is not available then the knowledge engineer will have the additional responsibility of (trying to) maintain an obsolete software package.

Techniques of Knowledge Representation In Education.

Currently the most popular type of knowledge representation technique is the use of rule based systems. Rules are the formal method for defining knowledge. This makes rules the choice when expert systems are based on empirical and heuristic knowledge. Using IF:THEN statements is a common technique of codifying knowledge. If the inputs match the IF portion, then the THEN portion is concluded. That is the firing or executing function. The firing is done via the inference engine. As a consequence of the firing of a rule, the dynamic knowledge base can be updated. Please see screen nine of Appendix B to see an interactive knowledge base updating. The knowledge base can be used by the rule interpreter (inference engine) to fire another rule. The result is a chain reaction: the production of inference chains. There are two types of inference chains: forward chains and backward chains. A forward chain is seeking new information while a backward chain is to confirm the existence of a situation.

Expert systems are an offspring of the Artificial Intelligence efforts of the 1970s. Expert systems emulate a human expert in seeking a well defined solution. The purpose of an expert system is to manipulate knowledge bases. The expert does this by using the expert's heuristics. Essentially, the expert system will limit the number of search paths via the intelligent use of the knowledge base. In an educational application, the expert system can be a teacher's aide.

RESISTOR TECHNOLOGY

Expert systems contain the knowledge of a well defined but narrow field. Integrating basic skills in technology education, specifically, component identification in electronics technology fits the criterion for expert systems. For the purpose of this project, our boundary was the knowledge engineering of the operational specifications of carbon based resistors.

Carbon Based Resistors: an Introduction

Resistors are electronic devices which offer a specific resistance to the flow of current. Carbon-based resistors are the most popular resistors. This is because they are relatively inexpensive to manufacture, are reliable, stable under most operating conditions and have a long service life. (Bratschun. 1971). General-purpose, component level carbon based resistors, i.e. discrete resistors, are commonly denoted: resistors.

To suit the particular electronic circuit application, there are many variations of resistors. Resistors are available in different resistance values, measured in Ohm units, ranging from 0.5 Ohms to over five hundred Mega Ohms. Tolerances of 5%, 10%, and 20% can be found in these types of resistors. For high accuracy, precision resistors with tolerances up to .005% are commonly used.

Construction of Carbon Based Resistors

Carbon–composition resistors are made in one of three ways. The raw materials are carbon black, a resin binder, and high refractory filling. These are combined in careful proportions to fit the resistance ratings. Next this blend is compressed into a cylindrical shape and then is cured in a furnace. After the curing, end connections are made by molding the ends of the wires directly into the carbon cylinder. Sometimes the resistor body is then sprayed with an insulating "organic" capsulate. The last step in manufacturing a carbon composition resistor is the application of the color code on the body.

The second resistor manufacturing process involves the use of ceramic insulation. An extruded rod of resistor material (manufactured similar to the resistor body mentioned above) is inserted into a tube of ceramic insulation. The ends are then capped with brass and sealed with a moisture resistant cement. Finally the color–code is applied. (Bratschun. 1971).

Another type of carbon–based resistor is the film–type. In this process, the main body of the resistor consists of a glass tube that is drawn through a liquid mixture similar in consistency to the aforementioned mixture. Leads are inserted into the glass body and cemented into place with a conducting adhesive that joins the leads to the film coating. These resistors can be manufactured to precise tolerances because of effective monitoring of the coating mixture. (Bratschun. 1971).

One other type of discrete resistor that is of interest is the deposited carbon resistor. This resistor is made by placing a ceramic rod in a container filled with a hydrocarbon gas and inert gas. The container is heated until a carbon film (that comes from the hydrocarbon gas) is deposited on the ceramic rod. This process is known as a "gas-cracking" process. By varying the temperature of the process and the time allowed for deposition of the carbon, films of varying thicknesses and properties are manufactured. The final resistance is determined by a helical pattern that is machined into the carbon film (Bratschun. 1971).

There are many other types of resistors whose construction are based on the carbon element. These include metal-film resistors, wire-wound resistors, pyrolytic resistors, and many more. The construction and materials are chosen for the electrical and physical characteristics of the resistor.

Resistor Color Bands

Aforementioned was the application of the color code bands to the resistor. Typically there are four bands, and the color bands designate the numerous resistor attributes. These bands are read from the one closest to the wire terminal, i.e. the first band is always adjacent the wire terminal. For obtaining the Ohmic resistance value, the first band is the first digit, the second band being the second digit and the third band is the multiplier (X10). Sometimes a fourth band is present, this being to signify the accuracy of the resistor. Rarely is a fifth band used; if present, it signifies military specifications, reliability characteristics and/or flame retardant qualities.

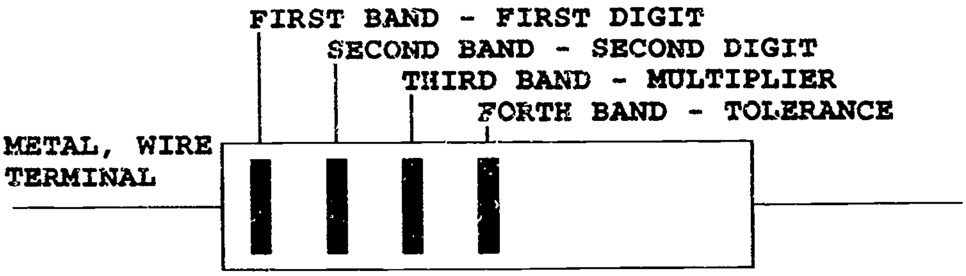

Figure 1. A Typical Resistor

The resistor is color coded, following a standard designation of colors to numerical values These are: Black = 0, Brown = 1, Red = 2, Orange = 3, Yellow = 4, Green = 5, Blue = 6, Violet = 7, Grey = 8 and White = 9. Thus a Brown Red Green Resistor has a resistance of 1.2 Mega Ohms i.e. 1,200,000 Ohms (from 1 2 5). Furthermore, since this resistor does not have a tolerance band, it is impled that the tolerance is 20%

These calculations are of fundamental nature in the skill level for an electronic technology student. Using the color code, they should be able to swiftly determine the resistance. That is not necessarily the experience of electronics instructors. Given the color code and a resistor, senior students can be found struggling to determine to numerical ratings of the resistor!

This expert system was developed to identify a resistor, according to the color code. The expert's heuristics determined the commonly available resistors; differentiating from the rare values. For this project, the knowledge bases used were of the principal investigator, the consultant and the knowledge encompassing commercial resistor kits. These were the heuristics utilized in curbing the paths for the inference engine of the expert system.

Expert systems are programs which pattern the thinking process of an expert in solving a problem in a well defined but narrow field. Identifying the characteristics of electronic components fits that criterion. This project's boundaries were to identify resistors, an electronic device which offers a specific resistance to the flow of current. There are commonly available resistors which were the heuristics utilized in curbing the paths for the inference engine of the expert system.

RESISTOR IDENTIFICATION EXPERT SYSTEM

The purpose of an expert system program is to facilitate a non–expert seeking solutions to a problem, in the same way an expert would have approached a similar problem. The method in which this expert system works is by asking an end–user a number of questions to help pinpoint a problem by narrowing down the answers. These questions are created by an expert in the specific field of resistor identification.

Building the Knowledge Base

In this project. the expert system is developed on MicroExpert. an expert system shell produced by McGraw Hill. The methodology used to solve a problem is presented in the form of rules. Rules are facts or statements written in an "If–Then" format. (given the "If" statements are true, subsequently the "then" must be true.) The file of rules is called a Knowledge Base. Knowledge Bases also contains prompts. The Prompts are questions that are written by the programmer to aid in solving the problem. Furthermore. the Knowledge Base contains attributes which are key words or phrases. In MicroExpert, these attributes consists of less than twenty characters and does not contain the word "and". There may also be translations which are phrases that can be used to describe the attribute in more detail to help in clarification of the attribute. (Thompson. 1985)

In writing a Knowledge Base, the most important step is to arrange the facts in some logical manner which would help in setting up a way to solve the problem. One way such technique is a decision tree. A decision tree could be as follows:

What is the color of the first color band, red or green?

The end user Answered: Red (Remember this is equal to two)

What is the color of the second color band, blue or black?

The end user Answered: Black (Remember this is Zero)

What is the color of the third color band, red or orange?

The end user Answered: Red (The multiplier, equal to two)

Based on these answers, one could conclude that the resistance Ohmic value of this resistor is 2,000 ohms.

Once the decision trees have been written, the next process is to produce the rules from one's tree. The following steps could be considered:

1. Write one rule for each branch of the decision tree that ends with a conclusion.
2. Give the rule a rule number.

3. Start the rule with the word "if".
4. Begin at the left side of the tree and write down each clause in the branch. Connect each clause with the word "and".
5. When one reaches the conclusion part of the branch, use the word "then".
6. Write down each clause in the conclusion, connecting each clause with the word "and".
7. End the rule with a line containing a period. (Please see Appendix A for listing of a rule base)

After the rules have been represented, prompt statements must be added. Each attribute (example: First color band) is assigned a prompt statement. A prompt is a question that will appear on the screen to ask the user for information about the attribute. Prompts are identified by the word "PROMPT", followed by the corresponding attribute. Only one prompt statement is allowed per attribute. Appendix A lists the Knowledge Base program written to find the Ohmic value of a resistor.

Interacting with the Knowledge Base

After the Knowledge Base has been completed, the MicroExpert has several commands which are as follows:

WHY	When asked WHY, the expert system is being queried. The system's response is to display the goal that is being searched for and the rule that is being used to try to find that goal. Each successive time WHY is typed, one sees the previous goal along with the rule being used to find its value until one reaches the main goal of the consultation.
HOW (N)	The lines displayed by each MicroExpert command are numbered. When one enters the command HOW, followed by a line number, the expert system will produce a description of how that clause was proved true or false, or, if the value is unknown, how it can be proved. Clauses can be proved either by a rule in the Knowledge Base or by information supplied by the user.

WHATIF (ANSWER)	WHATIF lets one see what conclusions can be drawn if given the specified response to the current prompt.
RULE (N)	RULE, followed by a rule number, displays the specified rule.
WHAT	WHAT displays all the facts derived during the consultation.
QUIT	The QUIT command is used to end the current consultation.

It is the interrogation of the expert system (via WHY, HOW, WHATIF, RULE, WHAT) that will assist the student in learning the thought patterns of the expert. In this project, the student will be able to follow the expert's (the classroom electronic teacher's) thought patterns in finding the resistance value. This because when the student queries the expert system, the heuristics used to encode the expert's knowledge will be reproduced. Thus the expert system will show the student how the expert would reach that particular goal. Therefore, the use of the expert system is not only to reach a final answer (example: the Ohmic value) but more significantly, it is also to learn problem solving techniques!

CONCLUSION

This research guide is the product of a research project for the integration of basic skills, specifically component identification, in electronics technology, using an expert system. The procedures utilized the MicroExpert shell, developing an expert system for resistor identification. For evaluation of the expert system, the facilities of the project's principal investigator and project consultant were utilized. These were actual classroom situations.

Application of computer Aided Instruction (CAI), specifically expert systems, can assist in technology education. The expert system developed in this project can be utilized in integrating basic electronics skills in technology. Using this project as a basis for developing ***real*** CAI applications, educators should be able to develop expert systems to assist them in their instructional programs. Furthermore, these intelligent assistants will establish supportive learning environments for the students.

There are three interlocking elements of this project. One is the student learning process. The second element is the resistor identification procedure. The third element is actually using the expert system.

A branch of Artificial Intelligence, Expert Systems contain the knowledge of a well defined but narrow field. Integrating basic skills in technology education, specifically, component identification in electronics technology fits that criterion. This project boundaries were to knowledge engineer the operational specifications of carbon based resistors.

Using expert systems does not constitute a complete teaching process. It is part of a guidance and/or reinforcement strategy of instruction.

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prompt first band
what is color of first band?
.

prompt second band
what is color of second band?
.

prompt 3rd band
what is color of 3rd band ?
.

prompt 4th band
what is color of 4th band ?
.

1
if first band is
then first digit is 2
.

2
if first band is brown
then first digit is 1
.

3
if first band is yellow
then first digit is 4
.

4
if second band is red
then second digit is 2
.

5
if second band is brown
then second digit is 1
.

6
if 3rd band is black
then multiplier is 1
.

7
if 3rd band is brown
then multiplier is 10
.

8
if first band is orange
then first digit is 3
.

9
if first band is green
then first digit is 5
.

10
if first band is blue
then first digit is 6
.

11
if first band is violet
then first digit is 7
.

12
if first band is gray
then first digit is 8
.

13
if first band is white
then first digit is 9
.

14
if second band is black
then second digit is 0
.

15
if second band is orange
then second digit is 3
.

16
if second band is yellow
then second digit is 4
.

17
if second band is green
then second digit is 5
.

18
if second band is blue
then second digit is 6
.

19
if second band is violet
then second digit is 7
.

20
if second band is gray
then second digit is 8
.

21
if second band is white
then second digit is 9
.

22
if 3rd band is red
then multiplier is 100
.

23
if 3rd band is orange
then multiplier is 1,000
.

24
if 3rd band is yellow
then multiplier is 10,000
.

25
if 3rd band is green
then multiplier is 100,000
.

26
if 3rd band is blue
then multiplier is 1,000,000
.

27
if 3rd band is gold
then multiplier is .1
.

28
if 3rd band is silver
then multiplier is .01
.

29
if 4th band is none
then tolerance is 20%
.

30
if 4th band is gold
then tolerance is 5%
.

31
if 4th band is silver
then tolerance is 10%
.

APPENDIX B. INTERACTIVE SESSION WITH THE EXPERT SYSTEM.

The following screens are reproductions of actual screens on the computer when the Microexpert program is executed. Microexpert is the expert system shell, the actual expert system/knowledge base is Resistor.kb

```
Knowledge Base (Enter 'Quit' to end the program) : Resistor
```

Screen 1

Please note: The small letter text is from the program, the large letter text was the response from the expert system user.

```
What is the final goal for this consultation?
```

Screen 2

At Screen 2, the system user pressed the enter key. Screen three shows the expert system response of showing the available conclusions.

```
What is the final goal for this consultation?

Valid goals are:

FIRST DIGIT        MULTIPLIER        SECOND DIGIT
TOLERANCE          QUIT
```

Screen 3

What is the final goal of this consultation?

First digit

Screen 4

The expert system user indicates the need to know the value for the first band.

What is the color of the first band? Why

Screen 5

In screen 5 to determine the Ohmic value for the first band, the expert system asks for the color of the first band. The user responds by asking the question why. This ability to question the expert system is a significant tutelage aspect of using expert systems.

The system is trying to find a value for FIRST DIGIT using rule 1

Rule 1
If
1) First Band is RED
Then
2) First Digit is 2

Screen 6

Screen 6 shows the expert system's response to the user's WHY. Note that the Rule 1 was developed not because it is digit one but because it was the electronics expert's heuristics that digit two would be the most common!

> What is the color of the first band?
> **Brown**

Screen 7

The user identifies the first color band. This example is to identify a one thousand Ohm resistor, tolerance of 10 %. Thus the device has the following color bands: brown, black, red and silver.

> Conclusion:
> FIRST DIGIT IS 1
> Press <Space Bar> to continue.

Screen 8

Screen 8 shows that the first digit has been determined to be one.

> The following facts have been determined:
> 1) First Digit is 1
> 2) First Band is Brown
>
> Do you want to perform another consultation with this knowledge base (Y/N) **y**

Screen 9

> What is the final goal for this consultation?
> **Second digit**

Screen 10

```
What is the color of the second band?  Black
```

Screen 11

```
Conclusion:
SECOND DIGIT   IS 0

Press <Space Bar> to continue.
```

Screen 12

```
The following facts have been determined:
1) Second digit            is 0
2) Second Band             is Black

Do you want to perform another consultation with this knowledge base (Y/N) Y
```

Screen 13

The following facts have been determined: 1. Multiplier is 100 2. 3rd Band is RED Do you want to perform another consultation with this knowledge base (Y/N) Y	

Screen 17

What is the color of the 4th Band? WHY	

Screen 18

The system is trying to find a value for TOLERANCE using rule no 29. Rule 29 IF 1) 4TH BAND IS NONE THEN	

Screen 19

Notice in screen 19, the expert system responded to the user's question WHY with an explanation why it asked the question and a rule that it was attempting to verify. This is an advantage of the expert system, it patiently and consistently will explain the questions asked . . . what a congenial and Socratic way to learn!

```
What is the color of the 4th Band?

Valid answers are:

NONE              NONE              SILVER
WHY        WHAT
RULE       HOW
WHATIF     QUIT
```

Screen 20

In screen 20, the valid answers are shown. Note the top line of the answers are from the expert's knowledge base, the remainder are from the development program. The system user responded with SILVER for the tolerance band.

Screen 21 shows the response from the expert system; it has correctly determined the tolerance to be ten percent.

```
Conclusion:
TOLERANCE          IS 10%

Press <space bar> to continue.
```

Screen 21

Thus the expert system successfully found out that this resistor has a tolerance of ten percent.

We have already determined that the first digit (from the color band red, screen 9) is two, the second digit (from the color band black, screen 13) is zero, and the multiplier (from the color band red, screen 17) is one hundred. Now from screen 22, we come to know the tolerance (from the silver band) is ten per cent.

```
The following facts have been determined.
1) TOLERANCE            IS 10%
2) 4TH BAND             IS SILVER

Do you want to perform another consultation with this knowledge base (Y/N) Y
```

Screen 22

This identifies a red, black, red, silver resistor as a 2000 Ohms, (2K Ohms) with a tolerance of 10 percent.

Screen 22 indicated continuation with the same knowledge base. In screen 23 shown is a WHATIF situation.

```
What is the color of the first band?

WHATIF ORANGE
```

Screen 23

In screen 23, the user is asking the expert system what would happen if the first band was orange.

```
The following conclusions are possible:
RULE 8
1) FIRST DIGIT          IS 3
Press <Space Bar> to continue.
```

Screen 24

As screen 24 shows the answer to the WHATIF question; note the expert system has answers for even a hypothetical situation!

APPENDIX B. EXPERT SYSTEM INTERACTIVE SESSION (CONTINUED)

What is the color of the first band?

Rule 4

Screen 25

Another feature of the expert system is its ability to answer/explain any rule. In screen 25, the user is asking for a definition of rule 4.

```
Rule 4

IF
 1) SECOND BAND          IS RED
THEN
 2) SECOND DIGIT         IS 2

Press <Space Bar> to continue
```

Screen 26

As screen 26 shows, the expert system shows the rule; thus the band number, color, and the corresponding ohmic value.

These screens, show an actual interaction with the expert system. Depicted here is the system finding the ohmic value for a resistor, answering why the expert system is asking certain questions at specific stages, giving hypothetical answers and explaining the rules.

GLOSSARY OF TERMS

Artificial Intelligence (AI). Concept where a machine (computers) can think like humans. Real AI has not been achieved. AI is also considered a viable option where natural intelligence is lacking.

Carbon Based Resistors. Resistors made with carbon; an element with four electrons in the valance shell, thus not a good conductor nor a good insulator. Also see resistors.

Carbon Black. Pulverized carbon, carbon powder.

Domain Specific Knowledge. Information about a certain subject. Typically the knowledge is complete, i.e. everything is known about this subject. Only an expert will know all there is to know about his/her subject.

Dynamic Knowledge Base. As the program is running, the program will learn from the question and answer session.

Empirical Knowledge. Information received via observation, experimentation and practical experience. Compare to formal and theoretical learning.

An Expert. One who combines empirical, formal and heuristic information into a usable concoction. Experts usually have a flair, a flamboyance regarding their wisdom.

Expert Systems. A computer program which can imitate the thought/action process of an human expert in dealing with the human expert's domain.

Expert System Development Tools. Commercially available computer programs which are used for writing expert systems. Expert System Development Tools are the same as word processors used for writing a letter.

FORTRAN. Acronym for Formula TRANslation. A computer programming language used for engineering. scientific and mathematical applications. Not a symbolic programming. Fortran is a traditional algorithmic programming technique.

Forward Chains and Backward Chains. A method of seeking answers in expert systems. where a forward chain is seeking new information while a backward chain is to confirm the existence of a situation.

Heuristics. Rule of thumb knowledge, self taught procedures. May not always be accurate or correct.

High Refractory Filling. A ceramic type material which has a very high melting point. Used as an inert binder in the manufacture of resistors. Helps in the resistors' ability to withstand high temperatures.

Inference Engine. Part of the expert system program which interprets rules. Depending upon the answers it receives, it validates selected rules, while ignoring others. The inference engine is part of the tools. The end user does not write the inference engine. Also known as a rule interpreter.

Knowledge Base. The listing of the rules. Includes the expert's formal, empirical and heuristic knowledge.

LISP Acronym for LISt Processing. A language used to write artificial intelligence programs. A symbolic language, based on lambda calculus. A LISP program is a listing of relationships, defined in terms of one another.

Metacognition. Cognition is broadly defined as comprehension or understanding. Metacognition is the understanding about how we comprehend information.

Ohm's Law. A fundamental relationship in electronics. It states that the current flow, I, (quantity of electrons, in amperes) is directly proportional to the voltage (force on the electrons, in volts) and is inversely proportional to the resistance (the opposition to the flow, in Ohms). Mathematically: $I = V/R$

Paradigm. A prototype. Used in the context that the first experience with a given expert system is a trial.

Pascal. A traditional, structured, non symbolic programming language. Named for a French mathematician, Pascal (1623-1662.) Orderly top down programming. Easy to use, like the BASIC language.

PROLOG. Acronym for PROgramming in LOGic. One of the most popular AI and expert system programming languages. Based upon a subset of predicate calculus. Inference rules must be used in determining truths, i.e. propositions result from a set of propositions; can infer S -> P using the inference rules.

Resin Binder. A glue like substance used in holding together the various ingredients in a carbon resistor. The binder is electrically inert.

Resistor. The most common electronic component. Resistors are used to provide a specific opposition to the flow of current. The also are used to provide an exact voltage. Also see Ohm's Law.

Rule Based Systems. Currently the most popular type of collecting intelligence to make up the knowledge base (see Knowledge Base.) Rules are a method for defining knowledge. Typically the rule uses IF:THEN statements to code the knowledge. If the inputs match the IF portion, then the THEN portion is concluded.

Rule interpreter. See Inference Engine.

Semantic checker. A useful feature found in editors. The semantic checker will flag the knowledge engineer if the currently entered rule conflicts with the existing knowledge base.

Socratic Method of Learning. The is an approach to learning, uses a technique of conducting a dialog to learn. This consists of merely asking questions that encourage a group discussion of the subject. During the discussion, the instructor observes how students react to the subject, what aspects of the subject stimulate the most interest, and with which aspects of the subject the students are most familiar. The Socratic method is for teaching and assessment. A caveat: based on the teachings of Socrates who was executed in 399 B.C.

Syntax Checking. Most expert system development tools have a method which checks the arrangement of words for correctness. This arrangement includes special function words (also see rule based system.) The special arrangement or application of these restricted words must meet predetermined relationships, i.e the syntax of the language.