

## **Developing instructional software**

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Software development for the computer in the classroom is becoming a growing concern for educational institutions. Many packages which claim to be "educational" fail to meet this criterion. By software we mean the program with which students interact when they are being taught by a computer and by development the adequacy of its educational merit. This paper attempts to highlight some basic design principles which will help overcome these problems.

The designing of educational software is similar to preparing for any act of classroom instruction. The designer should seek to enhance the instructional quality of the computer-based learning material by making sure that:

1. Information is presented or skills are modelled.
2. The student is guided through initial use of the information or skills.
3. The student practices until familiarity or fluency is gained.
4. Student learning is assessed (Alessi and Trollip, 1985, p.65).

The first element, presenting information, is to introduce students to something new. In a classroom situation, to help a group learn certain concepts, the instructor models the skills to be learned so that the students can imitate them. Although concepts can be presented in an abstract form it is necessary to demonstrate their practical application for students to retain the learned information. With computer-based instruction a similar strategy is employed in which the instructor's role is substituted by the educational software.

The second step in the process, guiding the student, is more interactive. Once the presentation has been observed, the student must now do something to apply the process. At this stage, the role of the instructor is to guide the student through the concept or the process being taught as well as to monitor each student's performance in order to correct any

misinterpretation of the information. Guidance is in the form of feedback. In the classroom context the instructor asks questions which students must answer. According to whether the answers are right or wrong the instructor then takes some particular action. Similarly with educational software frequent, clear, accurate and immediate feedback is important for students to be guided through the learning process.

The third stage, repeated practice, is to ensure that the student learns to perform the task quickly and efficiently with minimal or no error. During this stage, the instructor still observes the student's actions but, if need be, only gives short corrective directions. The assumption here is that with repetitive exercises the student will eventually perform the task promptly and effortlessly. With educational software this repeated practice is also an essential ingredient to ensure fluency. Repeated practice can take the form of intricate questioning to ensure that the new processes and concepts introduced earlier are fully understood or it can also include imitating real world situations to provide the student with real life depictions of a process or a series of events.

The fourth attribute of the instructional process is assessing the learning outcome, usually by means of tests. Whether in a classroom environment or through educational software, testing provides the means by which we can gauge how effectively the instructional message was delivered. In many ways it is the most important component of the instructional process because it provides the instructor or the educational software designer with information regarding the extent to which learning is occurring in order to determine future instructional strategies.

In summarising the model we have briefly described we find that the instructional quality of the educational software is maximised when four key elements are present: presenting information to students; guiding the student through the learning process; practising to promote fluency and retention; and finally, testing the students.

This does not mean that "all" the four elements should be present at the same time in all educational software. More often than not computers in the classroom are used alongside teachers and other media to complete the instructional process. Therefore the four elements are shared between them. However, if in the classroom the computer is responsible for the total instruction then all the elements should prevail. Alessi and Trollip (1985, p.63) classify educational software in five major types: tutorials, drills, games, simulations, and tests.

Tutorials are used to address the first two features of instruction: presenting information and guiding the student through the material to be learned. Tutorials can effectively deliver information that involves learning principles or problem-solving strategies.

Drills and games, on the other hand, basically engage in the third phase where practising is the key element.

Simulations are a little more complicated. They provide any combination of the four elements of the instructional process in the same lesson. Simulations are used to initiate a real situation in a controlled environment.

Tests usually represent the last phase which is that of assessing student learning.

Following is a combined analysis and detailed description of the development of an educational software package designed to both instruct and give students an opportunity to experiment with the flow of electricity in series circuits before they actually sit down with wires and batteries.

## **Description of the Software**

### *Overview*

The software, designed to teach the "Characteristics of Series Circuits", is a computer-based lesson of the Tutorial type which also includes some aspects of Drill, Simulation, a Test, and a Student Workbook. It has been specifically designed for first year students of the Automotive Electrical/Electronics apprenticeship at Richmond College of TAFE. It is the fourth of eight modules relating to the characteristics of basic electrical circuits.

The general objective of this educational software is to find answers to some of the questions and problems associated with series circuits. Many automotive electrical systems rely on the use of series circuits for their operation and failure to grasp the basic concepts of series circuits could result in damage to expensive sensors or control units.

The objective will be reached by working through the lesson which, at the initial stages, is designed to teach the concept of an electrical series circuit plus how to calculate various voltage and resistor values distributed over the component parts of the circuit. The latter part of the lesson includes simulated experiments to discover the effects that resistors connected in series have on the total circuit resistance and circuit current.

Students before they work through "Characteristics of Series Circuits", which is the fourth of eight modules related to electrical circuits, must have completed the previous three modules which cover Basic Automotive Circuits, Ohm's Law, and Characteristics of Basic Electrical Circuits.

The lesson has accompanying documentation in the form of a Student Workbook in which there is an introduction to the package; task directions; diagrams, calculations, and learning activities.

The lesson, together with learning activities, calculations, and the end test, should not take more than two hours to complete.

### ***Behavioural Objective***

The teaching of "Characteristics of Series Circuits" is based on behavioural psychology where the emphasis is on specifying the behavioural objective, analysing learning tasks and activities, and reaching specific levels of competency. The objective, written in behavioural terms, states:

At the end of this lesson the student, without assistance, should be able to correctly:

- a) define a "series circuit";
- b) perform calculations relating to series circuits;
- c) explain the effect which the connection of two or more resistors in series has on the total circuit resistance;
- d) explain the effect which the connection of resistors in series has upon the total circuit current.

## **Development of the Software**

### ***Logo***

The lesson begins with an opening screen which shows the College Logo. It is college policy to display the college logo at the beginning of any learning material that has been produced in-house. Its function is twofold: it gives the students some assurance that they are working through learning material that has been designed specifically for their course, and it also serves as identification for copyright purposes.

### ***Title Screen***

To indicate the nature of the lesson content, and "to create a receptive attitude" (Alessi and Trollip, 1985, p. 67) the next screen, which appears automatically after a short pause, is the title of the lesson: "Characteristics of Series Circuits".

### ***Objective/Rationale***

There is considerable debate about whether objectives should be used in purely behavioural terms or whether they should be concept-specific (Beech, 1983, pp.71-72). Nevertheless, a concise and accurate statement which includes what the students will be able to do at the end of the lesson and its relevance to their course of study is highly desirable (Alessi and Trollip, 1985, p.69). Therefore, in "Characteristics of Series Circuits" a combined general objective/rationale to describe 'what' the lesson is about and 'why' the lesson is important within the context of electrical circuits is

included in the next screen. However, the more precise objective, written in behavioural terms, is stated in the Student Workbook.

### ***Entry Level***

Educators agree that people learn new concepts only if they can build on what they already know (R. C. Anderson, 1977; Adams & Bruce, 1980; Rumelhart & Ortony, 1977; in Alessi and Trollip, 1985, p.71); especially when these new concepts require prior knowledge of a specialised technical vocabulary. For this reason, the next screen specifies the entry level of the lesson which is the completion of the previous three modules relating to the characteristics of electrical circuits. This screen also includes a brief overview of the related concepts and terminology studied in the previous modules in order to bring them to mind and use them in the lesson.

### ***Online Assistance***

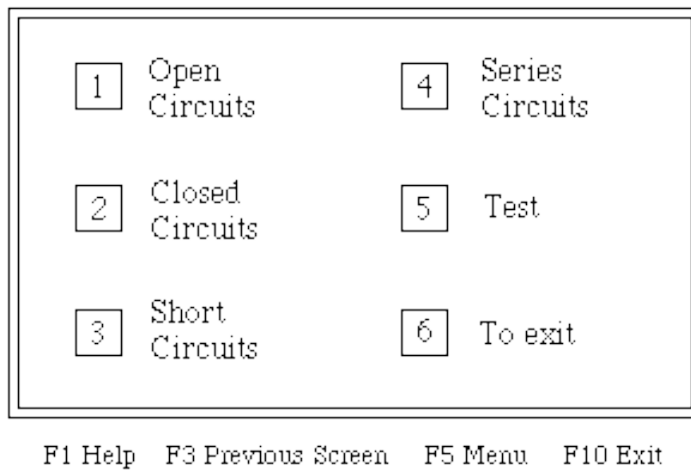
"Nothing can be more frustrating than being 'stuck' inside a program without any idea of what to do next" (Favaro, 1986, p.129). Therefore, the next screen:

- a) asks students whether or not they want instructions on how to use the software (Press Y or N);
- b) tells students how to get on-line help in case they get stuck and don't know how to proceed (Press F1 Key);
- c) tells students how to browse through previous screens to review earlier information whenever they want to do so during the lesson (Press F3 Key)
- d) tells students that the lesson is menu driven and how to access the Main Menu from any part of the lesson (Press F5 Key)
- e) tells students how to exit the program at any stage during the lesson (Press F10 Key).

This message is to provide students with information about a routine within the program that responds to procedural and informational help accessible at any point during the lesson. The message "F1-Help"; "F3-Previous Screen"; "F5-Main Menu"; and "F10-Exit" is displayed at the bottom of the screen throughout the lesson.

### ***Main Menu***

The next screen displays the Main Menu which allows students to choose where they wish to start in the lesson by selecting options from a list of topics (See Figure 1).



**Figure 1**

The major advantages of a menu is to "provide an obvious structure to the software" (Dumas, 1988, p.66) and "to 'break up' different sections of the program" (Favaro, 1986, p.128). This is to give students a more holistic approach to the lesson by allowing them control over which learning path they choose for themselves. In our case, to learn about the characteristics of series circuits students should already have an understanding of what is meant by open, closed, and short circuit. The lesson has been arranged in sections to give students the opportunity to revise any of these topics if they wish to do so at any stage during the lesson; ie. by going back to the menu and selecting the appropriate section. The menu also allows for the more advanced students, or students of any other ability level, to select right at the beginning the "Test" option in case they would like to assess their knowledge of series circuits before venturing into the lesson.

### **Branching**

At this stage, the students' path through the lesson begins where they select to go from the choices listed in the menu. Moreover, the flow of the lesson also takes one of several alternatives depending whether students master the material rapidly or vice versa. "Branching is the most prominent element that makes the computer a valuable tool for individualising instruction" (Schaefermeyer, 1990, p.9). In "Characteristics of Series Circuits" (See Flow Chart Figure 2) branching may take students forward in the lesson, meaning that they skip some information if they demonstrate competence in questions and exercises; sideways to remedial information when students identify unfamiliar areas of knowledge and record an incorrect response; or backwards to the previous screen (F3 Key) or to the Main Menu (F5 Key) if they choose to do so.

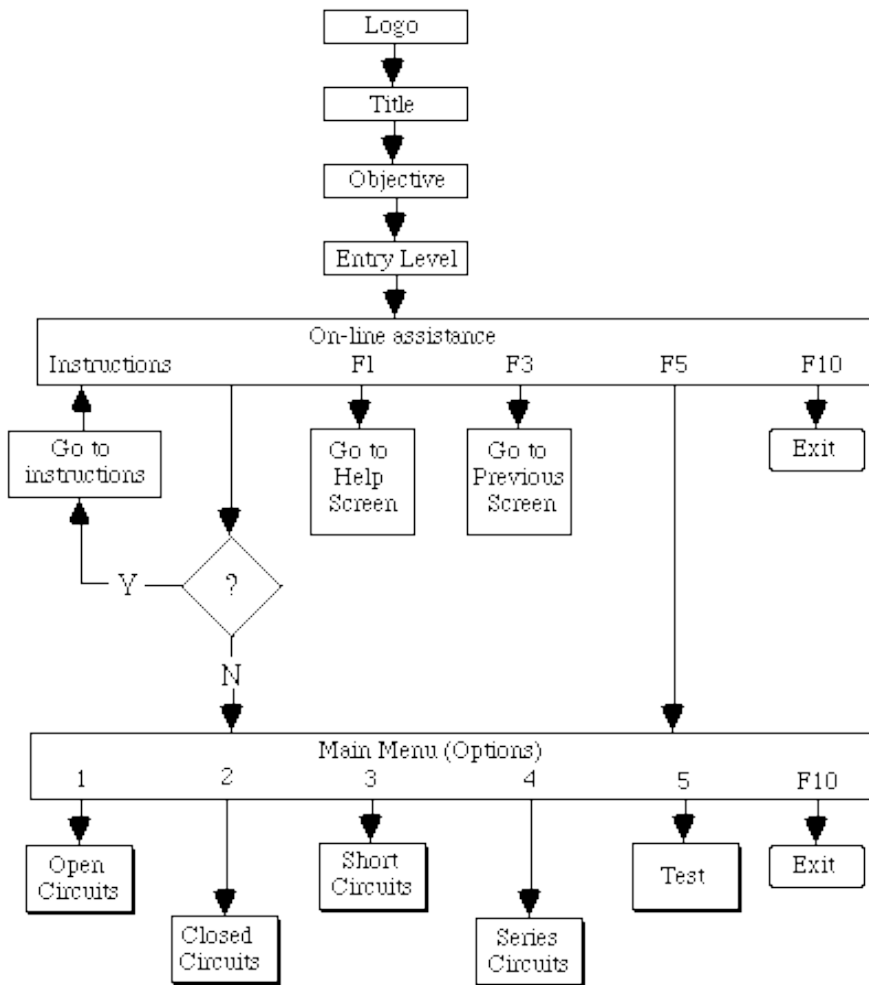


Figure 2A

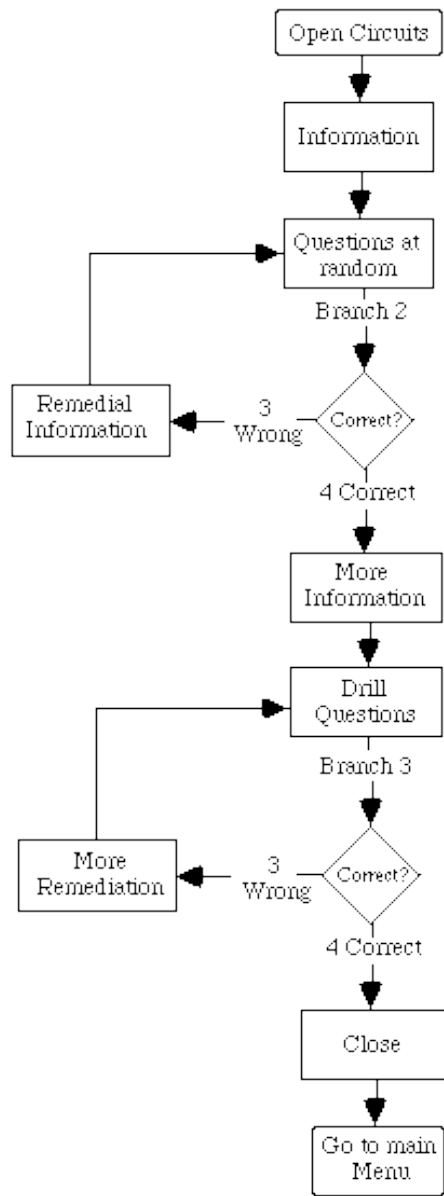


Figure 2B



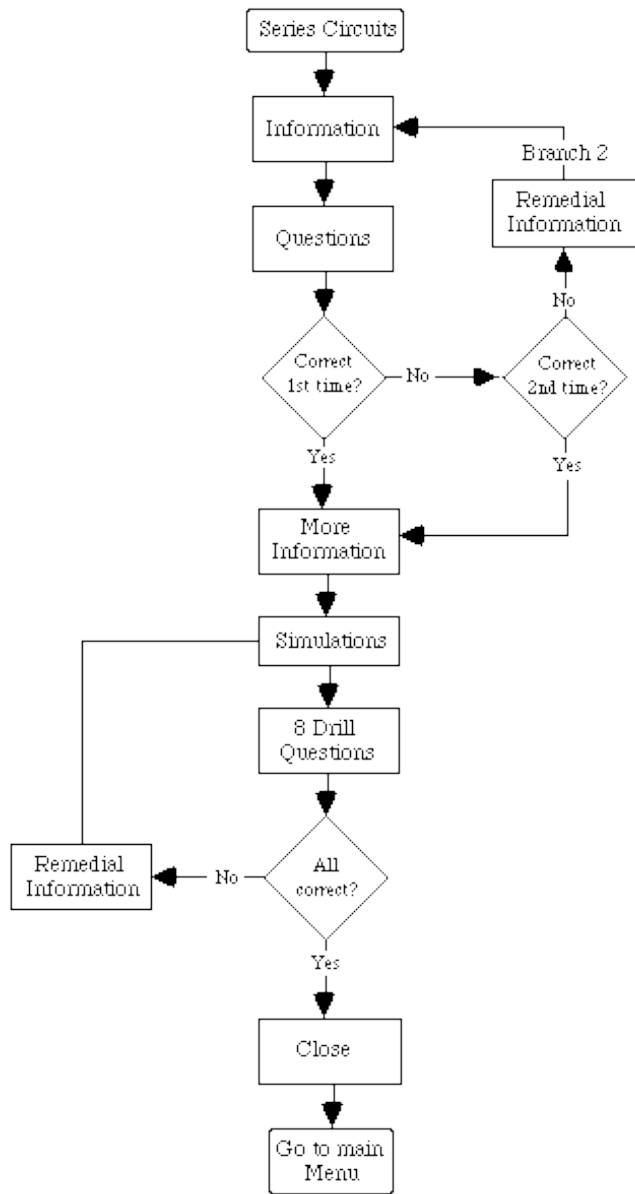


Figure 2C

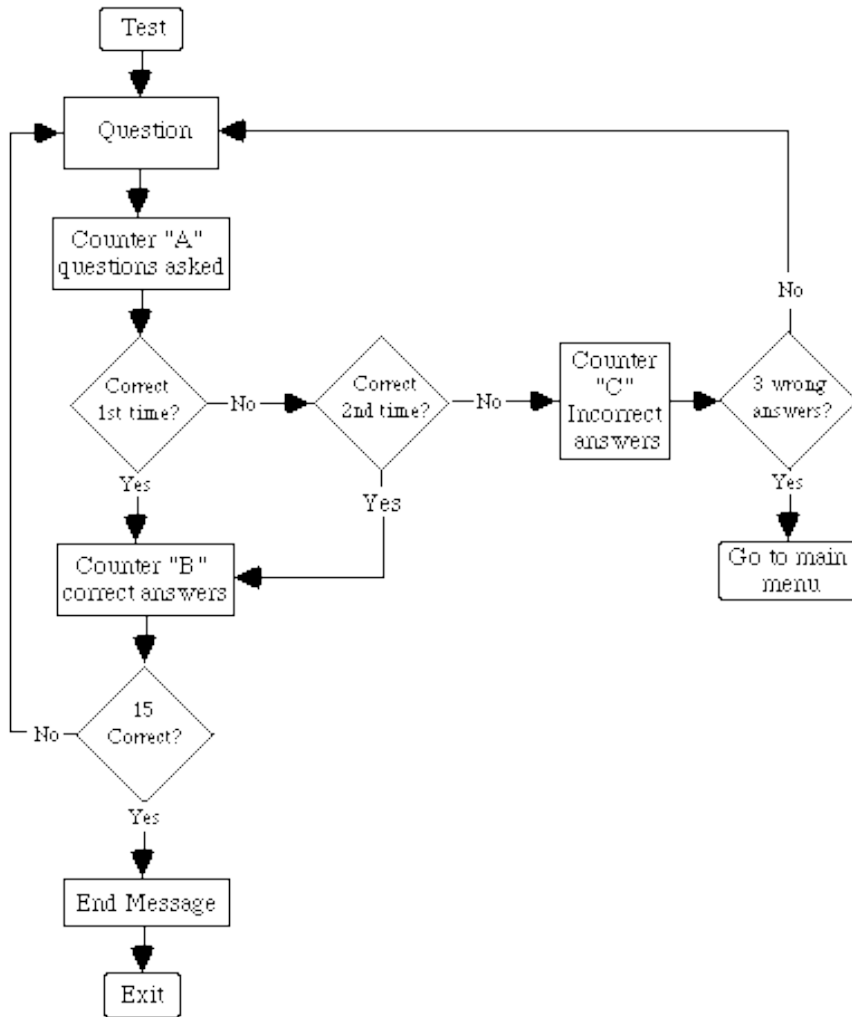


Figure 2D

**Flow of the lesson**

*Lesson Characteristics*

The first four sections of the lesson, open circuits, closed circuits, short circuits, and series circuits, all basically follow the same pattern: initial information is presented followed by questioning and exercises; wrong answers are erased and students are given a second attempt, total responses are then assessed and appropriate branching is chosen; more

information is given and the cycle starts again till the close of the section which takes students back to the Main Menu. On the other hand, section five, the test, is an assembly of fifteen questions and variable exercises, randomly selected from a 'pool' of fifty test items.

### ***Presentation of Information***

Information in each section of the lesson is presented in much the same way. It uses colour text screens, high resolution graphics and animation. Following are some of the considerations that have been observed in the layout of information screens.

### ***Text***

Text is displayed in upper and lower case with appropriate punctuation. It has a ragged right margin and avoids hyphenation. Titles and headings are provided for new information and a blank line is left between paragraphs which are kept fairly short to avoid inundating students with too much information at once. A symmetric balance is provided by centring the titles and headings and by placing information on both sides of the centre axis. The amount of text on each screen is just enough to maximise the frequency of student interaction. If information continues over multiple screens it is 'chunked' into smaller steps, each with a corresponding activity that requires a student response such as a specific exercise on the screen or in their Workbook, or to just 'Press SPACE BAR to continue'.

### ***Colour***

Colour is an effective means of grabbing and holding student attention. However, research literature "has very little to say on issues such as the 'best' colour in which to display information and the best mix of colours" (Dumas, 1988, p.103). In the lesson the following colours are used for the text screens:

- Blue - as background colour;
- White - plain, for all text (upper and lower case);
- White - bold, to emphasise important information;
- Yellow - for titles (upper case and boxed);
- Yellow - for headings (upper case);
- Magenta - for cues and prompts.

### ***High Resolution Graphics***

In "Characteristics of Series Circuits" certain concepts are described by using graphics in order to provide a visual model of the information to be learned (See Figure 3).

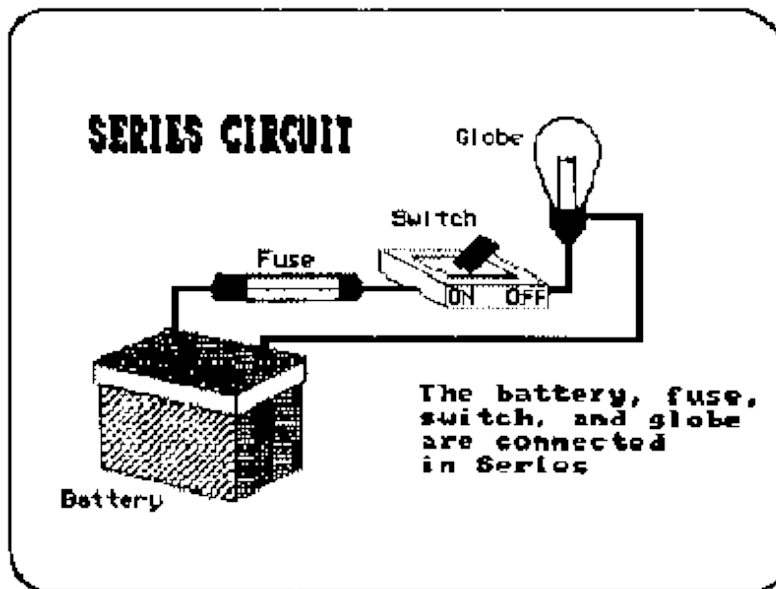


Figure 3

However, because "graphics must support and enhance the written portion of the lesson" (Burke, 1982, p.64), a lot of consideration and attention is given to their quality; that is:

- a) excessive detail is avoided to simplify and demonstrate a point more clearly;
- b) consistency is maintained to integrate each graphic into the total instructional message;
- c) more complex graphics are broken down into their constituent parts and then built up in a series of overlay screens;
- d) each graphic includes labels and text so that students can make informed comparisons and associations;
- e) all graphics are in colour and in high resolution to display accurate and sharp images.

### **Animation**

"Well-designed lessons with animation have improved student scores more than presentations with graphics and text or text alone" (Back and Layne, 1988; in Richards and Fukuzawa, 1989, p.24). In "Characteristics of Series Circuits" animation is used to demonstrate the successive stages in wiring up the various components of a series circuit (battery, fuse, switch, globe) and to show what happens to the current flow in an open circuit, a closed circuit, and a short circuit (See Figure 4).

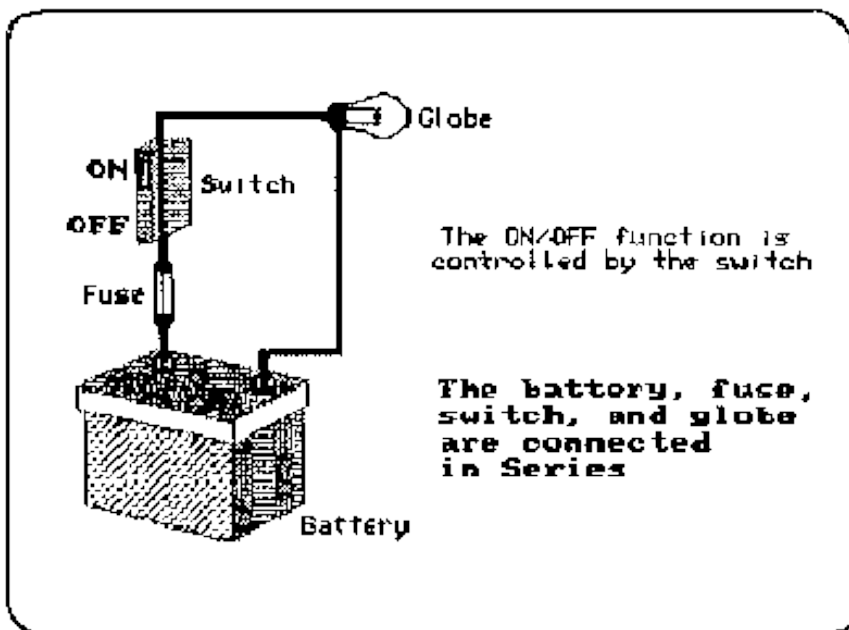


Figure 4

Students, especially when they visually follow the current flow, have no other way of seeing this except through animation on the computer.

**Questions**

To make the lesson as interactive as possible and to constantly assess how students are understanding the information in order to provide a relevant sequencing of the lesson, various questions are asked at selected places. The types of questions used are 'objective questions' because they are most likely to be appropriate when students have to "select from, discriminate between, or decide among a finite range of alternative possibilities" (Rowntree, 1986, p.310). Objective questions require students to either select a response such as in true/false, matching, and multiple-choice questions, or produce a response such as in completion or short-answer questions. All questions in the lesson are designed to reflect the instructional message and are asked after presentation of important information to enhance attention, provide reinforcement, assess learning, and select suitable branching.

**Student Responses**

The mode of student interaction to respond to questions is by using the keyboard. The major advantage of the keyboard over other input devices such as a light pen, touch sensitive screen or a mouse, is its flexibility as it can be used for both single letter or short-answer responses. In addition, the latter part of the lesson requires students to calculate various current and voltage values therefore numerical input must also be entered and the keyboard seems to be best suited for this operation.

**Response Prompt**

"A response prompt is a symbol that indicates the computer is awaiting a response" (Alessi and Trollip, 1985, p.106). The response prompt that the lesson uses is a flashing box immediately following a text instruction which explains what the student is to do; for example, "Select the correct answer (A,B,C,D,)". As a response is entered it will automatically appear to the right hand side of the flashing box. Care is taken to make the prompt clearly visible and students can make changes or revisions before finally entering their response by pressing the return key. On screen, the prompt appears two lines down from each question and as close as possible to the left margin to allow plenty of space for typing long answers.

**Feedback**

To inform students of their progress, encouraging and positive text messages are displayed after each response. When an answer is correct a randomly chosen message is given. Some of the messages for correct answers are: "good", "you know this bit", "correct". When a response is not accurate the first time a corrective message is displayed and the option to try a second time is provided. Some of these messages include: " Not quite correct, try again"; "It could be a typing error, try one more time"; "Please try once more". If at the second attempt students still answer wrongly then the correct answer is immediately displayed and the lesson branched out to the appropriate remediation section.

**Remediation**

In circumstances where the student is experiencing difficulty with the information being presented, remediation by branching to restatements of the information in simpler terms is provided. This may include more examples, simpler graphics, and more practice exercises with simpler parts of the material.

### **Simulations**

To satisfy the second half of the objective, that is to explain the effect which the connection of two or more resistors in series has on the total circuit resistance and the total current flow, the latter part of the lesson involves students to actively participate in simulating this real-life situation on computer. To investigate the current and voltage distribution in a series circuit, students are presented with a range of fixed resistors - 2 x 1k, 2k, 3k, 2 x 5k, a 0-5 mA Ammeter, a Voltmeter, and a 12 Volt power supply. The aim of the exercise is to allow students to trial a number of ideas and to discover the various effects. "The introduction of discovery learning has been strongly advocated for a number of years, because the student has greater interaction with the subject matter and is thus more likely to assimilate the knowledge, skills and concepts involved" (Woodhouse and McDougall, 1986, pp.78-79). In this simulation exercise students at all times are provided with feedback based on their choices, actions, and decisions. The cycle is repeated as many times students wish and it can be terminated at their command by pressing the F7 key to continue with the lesson or the F10 key to go back to the Main Menu.

### ***Drill and Practice***

Just before the close of each section of "Characteristics of Series Circuits" some drill questions and practice exercises are given to help students revise the new processes and concepts covered in the lesson. After each student response, immediate feedback is presented and attempts are made to explain why any incorrect answer is wrong. For example, when adding voltage drops in a circuit such as  $11.8 + 1.7$  and the student answers 12.5, then the feedback may be "You forgot the carry". A tally is displayed on screen of the number of questions presented and the number answered correctly and incorrectly. The drill and practice ends when students give a specified number of correct answers (see Flow Chart for different sections), or on their request by pressing the F10 key.

### ***Close***

To close each section of the lesson, a short paragraph is displayed to sum up the major topic points, to provide a list of suggestions for follow-up activities, and to direct the students back to the Main Menu.

### **Computerised testing**

Assessing student learning is the fourth stage of the learning model discussed earlier and testing provides the means to gather "information about the level of learning, the quality of teaching, and future instructional needs" (Alessi and Trollip, 1985, p.62). In "Characteristics of Series Circuits" the fifth option is in fact a test which requests students to answer correctly fifteen questions chosen at random by the computer from a pool of objective type questions and problems. The pool includes a batch of fifty

specific questions and at least one variable problem on each topic, meaning that the same problem is asked but varied each time by changing its numerical values. Students are provided with immediate feedback and the option to try a second time if a response is incorrect. After the second attempt the correct answer is given. A tally is kept for all correct and incorrect answers. Students complete the test when they score fifteen correct answers. However, if in the process of answering they score three incorrectly, the test automatically displays the message "Sorry! You have not mastered the topic yet" and branches back to the Main Menu.

### ***Storing Test Results***

All test results and individual response patterns are stored for future reference in order to establish whether or not a student has mastered the topic and to evaluate the lesson content. Evaluation is an important factor in the production of high-quality educational software. It suggests modifications where necessary and reveals the degree of effectiveness in meeting the goals of instructional efficiency. In the end we should have a lesson that "is functional, pleasing to look at, and presents its information in a manner conducive to learning" (Alessi and Trollip, 1985, p.391).

### ***End Message***

At the successful completion of the test, a farewell message is displayed which includes the final score, feedback on the results, and how to exit the program. A typical end message would read:

Well done! You have passed. You have answered 15 correct questions out of 16 for a total score of 93.75%. Press F10 to Exit. Bye

### **Conclusion**

Developing educationally sound software is not an easy task. It is not something which comes naturally to most people. Rather it's the result of careful planning and scrupulous consideration of principles and techniques from various disciplines. The usual temptation when developing educational software is to sit at a terminal and bang away until something runs. That's not only inadequate but loses sight of the whole integrated relationship of students, subject matter, goals, and machine. This is why it is imperative that a rational approach be taken to ensure that each screen, each branch, each feedback message is used to enhance the teaching and learning process. Computers are of great value and no media, other than a teacher for each student, offers the same flexibility as a well-developed computer-based lesson. Learning is a complex process and we are only at the beginning of what one might call the path to "educational perfection" but developing effective educational software is indubitably one step forward towards that direction.



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<http://www.ascilite.org.au/ajet/ajet8/pellone.html>