The development of computer-assisted instruction (CAI) using the ABC authoring system for teaching basic electronics

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by

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A Thesis Submitted to the Graduate Faculty in Partial Fulfillment of the Requirements for the Degree of MASTER OF SCIENCE

Department: Industrial Education and Technology Major: Industrial Education and Technology

Signatures have been redacted for privacy

Iowa State University
Ames, Iowa
1994
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CHAPTER I. INTRODUCTION

Recently, educators have gained access to a wide variety of instructional technologies to support teaching and learning. An emerging technology that is particularly appropriate for teaching electronics is the microcomputer. Prior to 1981, there were fewer than 30,000 microcomputers in U.S. schools, but by 1990 the number grew to more than 2 million (Roth et al., 1990). The availability of microcomputers in schools and their potential for helping achieve educational goals make them an ideal instructional tool (Imel, 1992).

A wide range of instructional approaches is available on the computer. The most common types of instruction are drill and practice, simulation, tutorials, and games. Computerized drill and practice offers repeated opportunity for developing speed and accuracy necessary in certain subjects. It also offers immediate feedback and error correction, which increases both efficiency and motivation (Sloane, 1989).

In the last twenty-five years significant resources and time have been invested in computer assisted instruction (CAI) (Levin et al., 1987). A number of experimental studies have been conducted to access the effectiveness of various CAI software packages. These studies, especially those conducted recently, tend to conclude that CAI does enhance achievement in the absence of any other programmed instructional material (Nordstrom, 1988).

There is ample evidence that CAI is both very effective and efficient. Recent research has argued that CAI leads to faster learning with better comprehension, retention, completion rate, and attitudes, when compared with more traditional educational approaches (Bright, 1983). Students learn more
material or retain more of what they have learned. There is a higher student
completion rate for courses of study using CAI (Levin et al., 1987).

In addition, a meta-analysis conducted by Kulik (1985) produced some
interesting results concerning the effectiveness of CAI. Kulik concluded that
computer-based education has had positive effects on student learning.

Others, such as Richard Clark, however, presented a different summary
of the research on CAI. Clark critiqued Kulik's meta-analyses and reported that
the achievement gains attributed to the computer mode were probably due to
the method of teaching used by the software, especially, the difference between
the way the teacher taught and the way the computer program presented the
instruction (Simonson & Thompson, 1990).

Although many studies have demonstrated that CAI can be an effective
form of instruction, these studies also indicate that simply placing some
materials on a computer will not improve its effectiveness (Clark, 1983). These
contrary interpretations of the research data occur because they explain the
information according to different sets of rules. Probably neither are absolutely
correct. The advantages of using computers in specific situations and for
teaching specific topics should be the focus of research efforts (Simonson &
Thompson, 1990).

It is important that effective CAI should be carefully developed for a
special topic. The development of CAI using the ABC authoring system for
teaching basic electronics is considered in the present research study. ABC is an
object-oriented programming system which is designed for development of
instructional applications (Boysen, 1994).
Statement of the Problem

This study was designed to develop a computer-assisted instruction (CAI) lesson using the ABC authoring system for teaching basic electronics and to evaluate some aspects of the lesson by investigating the students' perceptions after completing the lesson.

Objectives of the Study

The objectives of the study were to:

1. design and develop a CAI lesson employing the ABC authoring system which could be used for teaching basic electronics; and
2. evaluate some aspects of the lesson by investigating the students' perceptions after completing the lesson and by viewing videotape of the students who were learning the lesson.

Research Questions

This study was conducted to answer the following questions:

1. How can the ABC authoring system be used to design and develop a CAI program for teaching basic electronics?
2. What will be the students' perceptions about the CAI lesson concerning the following aspects: (a) subject matter; (b) presentation; (c) student interaction; and (d) program interaction?
3. Will the students learn anything from the lesson?

Procedures of the Study

The procedures for this research study involved three major steps. The first step was to design and develop the CAI lesson using the ABC authoring
system. The second step was to administer the CAI lesson and collect data. The final step was to analyze and summarize the data obtained through observation and testing of the students.

The procedures of the study were as follows:

1. Development the CAI Lesson
   - Review the related literature
   - Review the ABC authoring system
   - Identify some concepts in basic electronics
   - Design the presentation techniques
   - Develop a CAI lesson
   - Make the lesson available for the public
   - Have an expert review the lesson
   - Perform some revisions

2. Data Collection
   - Obtain approval from the University Human Subjects Review Committee
   - Arrange for data collection
   - Administer a pretest one week before administering the CAI lesson
   - Administer the CAI lesson and videotape the subjects
   - Administer the questionnaires and a post-test

3. Data Analysis and Summarizing
   - Code and categorize data from the questionnaires
   - Analyze data from questionnaires and achievement tests
   - Analyze data from the videotape
   - Summarize the data
Limitations of the Study

This study was conducted under the following limitations:

1. The CAI lesson covered some basic topics on DC circuits: basic quantities, Ohm's Law, series circuit, parallel circuits, and series-parallel circuits.
2. The CAI lesson could be accessed from the Project Vincent terminal.
3. The subjects of the study were undergraduate students at Iowa State University who were not taking and had not taken any college-level electronics class.

Definition of Terms

**ABC**: an object-oriented programming system which was designed at Iowa State University for the development of instructional applications (Boysen, 1994).

**Authoring Language**: a special-purpose computer language that is designed expressly to facilitate the writing of educational programs (Maddux, 1992).

**Click**: when a mouse is used, pushing the button on it is called "clicking."

**Computer-Assisted Instruction**: the use of the computer as an aid in the teaching/learning process.

**Courseware**: a specialized type of software that provides course content instruction via computer program (Chambers, 1983).

**Method**: a term in the ABC authoring system as a function in C Language or a procedure in Pascal. A method defines how an operation is performed.
CHAPTER II. REVIEW OF LITERATURE

Computer Assisted Instruction

The nature of CAI is either a totally new instructional medium with the ability to deliver unique instruction, or simply a better and faster delivery system for traditional instruction. Many discussions related to CAI are currently available in the literature. Ross and Anand (1987), for example, suggested that the learning benefits should be independent of the delivery system if the instructional theory underlying the strategy for teaching is valid. They stated; “Should benefits be restricted to CAI, however, one might therefore some unique contribution that makes to change the strategy’s impact” (p. 152).

Most of the current research on CAI effectiveness approaches the problem by comparing this new instructional delivery system with older or more conventional instructional media such as traditional classroom lectures, illustrated textbooks, programmed instruction texts, movies, videotapes or some combination of these. Several research designs have been used in CAI research; among them, case studies, correlation, causal comparative, and experimental research. Research reviews have also been conducted. These consist of box score tabulations and meta-analytic studies (Colorado, 1988).

Ross and Anand (1987) conducted a review of the literature on CAI and identified a number of ways in which CAI adapts instruction to individuals and delivers instruction superior to that of its predecessors. It does so by individualizing the following factors: the quantity of instructional support, the incentive value of tasks, the types of examples presented, and the exposure time
of lesson frames. It is impossible to find these kinds of strategies in a textbook or lecture presentation.

There is a great deal of research of a general nature, concerned neither with special populations nor with program variables, yet it is still oriented toward the factors that make CAI effective (or in some cases, ineffective). A number of these are meta-analyses. For example, Kulik (1985) conducted a meta-analysis of the findings of twenty years of research on the effectiveness of CAI. Among the overall results of this study were that students generally learned more when they received help from computers; students retained this learning longer; they required less instructional time to learn; students liked their classes more; and they develop positive attitudes toward the computer. In addition, there were variations in reported effects relative to study designs. The positive effects of CBE were stronger in published studies; effects were stronger in short studies and weaker in long ones; effects were stronger in more recent studies; and effects were stronger when different teachers taught the experimental and control groups.

Kulik et al. (1980) reviewed research on CBI at the college level and indicated that CBI had a modest positive effect for advanced learners. Their meta-analysis of 59 studies indicated that CBI produced gains of approximately .25 standard deviation units on content mastery examinations for college-level courses, an effect that was found uniformly across student ability level. Moreover, students tended to have a more positive attitude toward courses that included computer instruction. More importantly, in every study in which computer-based instruction was substituted for traditional teaching, the
computer group completed the instruction in about two-thirds or less time than is required by traditional teaching methods (Hasselbring, 1986).

Kulik et al. (1983) reviewed problems in early studies of CAI in an effort to summarize the results. Fifty-one independent experimental studies that used CAI in grades six through twelve were analyzed. They found that when CAI was used in instruction, student scores on final examinations were raised from the 50th to the 63th percentile which represented an increase of .32 standard deviation units. In addition, they reported that student attitudes toward the subject being learned and the student ratings of quality of instruction are slightly more favorable with CAI. Further, students' attitudes toward computers are significantly more positive as a result of CAI.

Others, such as Richard Clark (1985), however, presented a different summary of the research on CAI and stated that computers are not the powerful instructional tools that Kulik's results seem to indicate. According to Clark, the studies included in Kulik's reviews suffered from two critical problems. First, many were poorly designed; in other words, correct research procedures were not followed. Second, students in the CAI classes tended to receive enhanced instruction, either in the form of more time learning the skill in question or in the form of better prepared instruction.

Clark supported these claims by re-examining a random sample of the studies Kulik had also investigated and reported that, in 75% of the studies, serious design flaws were found. In over 50% of the studies, there were obvious failures to control the amount of instruction received by the computer and the traditional instruction groups. Instructional method was not controlled in one-half of the studies. When it was, there was no difference between achievement
scores for computer students when compared to traditionally taught students (Simonson & Thompson, 1990).

Campbell et al. (1987) conducted a study comparing the effects of CAI and traditional print methods, both for drill and practice, among third-grade students of math. Results of the study indicated that there was no significant effect of CAI. A greater number of students in the print drill and practice group achieved a mastery level and at a faster rate, but no statistical difference was found in overall performance.

While a great deal of literature in the form of speculation and editorializing has been devoted to the potential effectiveness of CAI, the evaluation of computer-based learning has been focused, in a large part, on learner achievement (Rockman, 1989). In a survey of over 8,000 teachers and principals, Becker (1987) found that educators advocating the use of computers believed significant benefits occurred in four basic areas: (1) students' motivation; (2) students' cooperation and independence; (3) opportunities for high-ability students in programming activities; and (4) in other higher-order thinking and writing skills, and opportunities for low-ability students to master basic math and language arts skills. Specifically, the teachers saw computers as primarily helping students to enjoy their school experience more and motivating them to pay attention to academic work (Hoffer et al., 1992).

Supporting these ideas, Kulik et al. (1985) encouraged the evaluation of computer-based education in terms of attitude towards computers, students' attitude toward instruction and subject matter and also the amount of time needed for instruction. Furthermore, Kulik and Kulik (1986) examined student attitudes towards the use of computer-based learning in eleven studies reporting
that contact with the computer in many cases produced positive changes in students' attitudes, and seven of the eleven studies reported more favorable attitudes for students in the computer assisted group.

Among the most commonly cited factors in the apparent success of CAI in contrast with traditional modes of instruction are such constructs as motivation and confidence. For example, De Blassio and Bell (1981) sought to determine the relationships between students' attitudes toward the use of computers and following variables: attitudes toward mathematics, attitudes toward the instructional setting, achievement in mathematics, achievement in computer programming, intelligence, and sex. They administered attitude surveys, a personal profile and inventory, and an anxiety scale questionnaire, and correlated the resulting data with student records. Their study concluded that the best predictors of attitude toward using a computer were attitude toward the instructional setting, aptitude for mathematics, and achievement in programming. However, no significant relation was found between attitude toward using the computer and intelligence (Nordstrom, 1988).

Swadener and Hannafin (1987) reported the use of a Likert-scale instrument to measure the attitudes toward the use of computers among sixth-graders. The authors placed possible variations in those attitudes in four categories: self-confidence in the use computers, perceived utility of computers, general attitude toward computers, and sex role in computers. A significant correlation was found between math achievement and confidence in using computers.
CAI Lesson Design

If students are to learn from computer-assisted instruction, the lessons delivered by computers must be carefully conceived and designed (Lilie et al., 1989). As Clark (1983) mentioned, simply placing some material on a computer will not improve effectiveness. The computer, itself, does not improve the quality of instruction that is programmed into its memory.

The study of what makes CAI effective is remarkably similar to the study of what makes instruction effective. Computer-assisted instruction is simply one form of instruction or one way of storing and delivering instruction. Thus, CAI can deliver very poor instruction as easily as it can deliver very good instruction. The difference between poor instruction and good instruction has little to do with computers and much to do with how the instruction is designed (Lilie et al., 1989).

According to Alessi (1985) the successful instruction must include the following four activities: (1) information is presented or skills are modeled; (2) the student is guided through initial use of the information or skills; (3) the student practices until familiarity or fluency is gained; and (4) student learning is assessed. The CAI lesson may serve any combination of the four phases, however, when the computer is responsible for total instruction, it is important that all four phases be included.

Furthermore, Alessi (1985) also categorized the CAI lesson into five major types: tutorials, drills, simulations, games, and tests. One of the first uses of the computer in education was for drill and practice (Simonson & Thompson, 1990). Using the computer for drill and practice activities provides several advantages over the traditional method. Probably the most obvious advantage of computer
drill and practice is that students can receive immediate feedback to their responses (Armour-Thomas et al., 1987). Feedback during computer assisted instruction helps to promote retention of material presented (Chanond, 1988). In a drill and practice CBI lesson the learners are practicing the use of knowledge or skills that have been previously acquired (Lilie et al., 1989).

In tutorial CAI lessons the student is given information to assist with the attainment of new knowledge and skills. A well-designed computer tutorial can offer opportunities for the student to interact with the material being presented. Tutorials are used in almost every subject area from the humanities to the social and physical sciences. They are appropriate for presenting factual information, for learning rules and principles, or for learning problem-solving strategies (Gagne et al., 1981).

Some studies showed that presenting the lesson objectives and introducing the lesson properly has been correlated positively with high achievement (Kozma, 1982). Common sense suggests, and research confirms, that students learn more when difficult words and long phrases are avoided, transitions are made smoothly, and a lesson moves forward with minimal interruptions and distractions (Smith & Cotten, 1980).

Studies done with students ranging from kindergarten to college indicate a consistent and relatively strong relationship between the number of relevant examples and demonstrations used, and student achievement. Research suggests that effective teachers use more examples for difficult concepts and principles than they do for less difficult ones (Emmer & Sanford, 1981).

Effective CAI programs include clear directions and assignments (Lilie et al., 1989). Studies at various grade levels have found a consistent relationship
between clarity in giving directions and making assignments, and student achievement (Emmeret al., 1982). Other studies have examined the impact of how teachers respond to correct student responses (Evertson, 1978). This principle suggests that effective CAI programs confirm correct responses and move on.

### Evaluation of CAI

The ultimate purpose of the evaluation of instructional software is to determine its level of validity (Lilie et al., 1989). Validity refers to the degree to which an instructional software program does what it is supposed to do.

Many studies and papers were as concerned with the methods of research in CAI as with the substance of that research. The research methodology is, of course, intricately related to its findings. For example, the inadequacy of software is related to the difficulty in evaluating the software itself and CAI in general.

According to Taylor (1987), over 10,000 elementary and secondary-level software packages were available at the time of publication, but only about a quarter of them had received adequate evaluation. Because of the complexity of software evaluation, the author recommended reducing the evaluation process to only three factors: objectives, feedback, and learner control.

Among the kinds of feedback that might be used in a CAI package are recognition (praise and reward), special enrichment learning activities, and graphic representation of progress. Learner control includes control of content (such as the lesson, sequence, or module) and control of strategy (such as elaboration levels, examples, or practice exercises).
A number of recent research papers were concerned with methods for evaluating software, and in some cases recommended their own methods or instrumentation for evaluation. For example, Budoff and Hutten (1982) presented six criteria for evaluating the design quality of instructional software: (1) individualized instruction with immediate and frequent feedback; (2) presentation of a comprehensive curriculum organized into a hierarchy of skills; (3) articulation of performance objectives; (4) measurement of progress by mastery of objectives; (5) use of diagnostic and prescriptive strategies to place the learner; and (6) a multisensory learning format.

According to Lilie et al. (1989), a comprehensive evaluation of computer courseware should include a review of three main aspects: (1) instructional content; (2) instructional procedures; and (3) instructional management. Instructional content refers to the subject of the instruction. To evaluate the appropriateness of the courseware it is important that the content is presented accurately and clearly, with the proper emphasis on the main points or principles to be learned.

Evaluation of the instructional procedures incorporated into the courseware is based on the accepted and proven principles of instructional design. This aspect of courseware evaluation responds to the general question of how the courseware is designed to optimize learning within a CBI format and is based on the instructional design principles. Finally, the evaluation should take into account the instructional management features of the courseware.

Caffarella (1987) developed an evaluation form to be used by teachers for assessing the effectiveness of software. The instrument included a number of open-ended questions and numerous Likert-scale questions. The open-ended
questions concerned some topics such as the program goals, the program content, and the intended audience of the program. The Likert-scale questions addressed the same topics as well as others such as instructional strategies used in the program, program design, appropriate use of computers, program techniques, a cost analysis, and overall evaluation.

The National Center for Research in Vocational Education (1987) developed a CAI lesson evaluation form to be used widely in technical and vocational area. The evaluation form is broken down into several aspects: subject matter, technical presentation, student interaction, program interaction, student evaluation, documentation, work behavior, and application program.

The aspect of subject matter is designed to ask whether the CAI program has educational values. The technical presentation aspect contains some questions to check if the program is free of any kind of malfunctions. The student interaction will ask the users whether the students are actively involved with the program. The aspect of student evaluation is designed in order to see if the program evaluation adequately measures the students progress. The evaluation form also determines if the package program has sufficient documentation to run the program. The last aspect of the form is the application program which is designed to check if the program performs the task for which it is intended.

**Authoring Tools**

Authoring tools to facilitate the production of instructional software have been available for over twenty-five years. They are currently proliferating in recognition of the greater need for instructional software. Literature on the
availability of such tools and the differences among them has increased. Also, questions concerning the "best" approach for developing instructional software have often been the subject of debate. However, very few guidelines exist for choosing among the alternative authoring tools or for setting criteria for the ideal instructional software authoring tool of the future (Hazen, 1987).

There are several levels of computer languages which can be classified as authoring tools. These include machine language, assembly language, high level language, authoring language, and authoring system (Merrill, 1985). It is apparent to anyone who has had programming experience that there are advantages and disadvantages for any point along this scale. At the machine/assembly language level there is maximum control over a particular computer. However, the level of effort required for even simple procedures is considerable. With higher-level languages or general purpose languages (e.g., Pascal, Basic, and C), the programming tasks become easier but the flexibility reduces.

Because the general requirements and format of most educational computing software programs are specific and similar, authoring languages have been created specially for teachers and educators who wish to create software for their students (Simonson & Thompson, 1990). Authoring languages (e.g., Pilot, TUTOR, and Topic) are special purpose computer languages that have been designed expressly to facilitate the writing of educational programs (Maddux, 1992).

Graphics and sound editors usually are included in an authoring language, and these features allow the teacher/author to use these features to enhance the effectiveness of the program. Many modern authoring languages
also provide the means for using the computer for instruction in conjunction with other media. Here, the computer is programmed to control the use of the accompanying media, as well as to interact instructionally with the student (Simonson & Thompson, 1990).

Authoring systems make use of a step-by-step approach to lesson design featuring prompting of the author by the software (Lockard et al., 1990). Their main advantage is their simplicity. Davis and Budoff (1986) emphasized this point: authoring systems (e.g., PLATO, TICCIT, and ABC) allow beginning programmers to construct lessons that look very professional. In addition, the authoring task is greatly simplified because the directions are usually presented on-screen in an easy-to-follow, step-by-step format.

Another advantage is that some authoring systems include highly sophisticated features that most programmers would be unable to duplicate with a traditional language. Such features include answer-matching and record-keeping functions (Lockard et al., 1990). Some authoring systems will permit integration of other hardware such as videodisk players, scanners, or other equipment that would be difficult to include in a lesson written in a traditional programming language.

According to Merrill (1985), there are three major advantages to an authoring system over an authoring language. First, most authoring systems attempt to minimize or eliminate programming by providing a series of menu driven editors. Second, authoring systems attempt to facilitate the instructional process by including a student management system. Third, authoring systems attempt to facilitate the instructional design process by including instructional templates.
The disadvantages of authoring systems are due to their lack of flexibility. Because they make authoring simple, even the best systems restrict alternatives and reduce the number of available teaching strategies (Mandell & Mandell, 1989).

The computer is used as an educational medium in such a large variety of ways that no single authoring language or system can be expected to meet everyone's needs. Decisions concerning which tool to adopt (whether a language with or without subroutines or an authoring system) need to reflect a set of criteria which best represents the need of a particular project's instructional software.

From an instructional design perspective, the research and experience of the last twenty years have indicated that certain features are highly desirable if not essential. For example, one of the most important design features for high quality instructional software is frequent interaction between the lesson and the student. High quality interaction includes appropriate feedback to student responses. Possible feedback situations are those for anticipated correct and incorrect responses, and for unanticipated responses. Authoring tools should facilitate this feature as thoroughly and as efficiently as possible. Therefore, it is desirable that student responses be processed rapidly and that feedback be provided quickly (Hazen, 1987).

Choosing the appropriate media for any given task is important. For example, graphics are highly desirable in mathematics instructional software for illustrating mathematical functions, or in electronics instructional software for illustrating various components and instruments. Sound may be more desirable for music instructional software. Interfacing with a videotape, sound tape,
sound synthesizers, and videodisc further enhances the instructional software's ability to provide individualized instruction. As media are needed within a lesson, an authoring tool needs to facilitate access to the desired medium.

Learner control is becoming an increasingly important factor in computerized instruction (Cohen, 1983). Many students benefit from interacting with instructional software in a flexible skip-back-and-forward fashion under the learner's control, and this feature enhances the computer's ability to provide truly individualized instruction. Such flexibility requires programming routines to allow ready student access to glossaries, definitions, objectives, overviews, menus, and other organizing or helping functions (Hazen, 1987).

Alternate fonts or letter sizes and letter colors are extremely useful for highlighting key concepts (Steinberg, 1984). These techniques focus a student's attention on the most salient concepts or words within a screen. Authoring tools need to be able to facilitate color and size changes for text characters.

Hazen (1987) gave a set of criteria which are particularly important to the instructional designer include authoring tool's ability to:

- provide features to encourage highly interactive software and rapid response times.
- facilitate alternative modes such as drill, practice, simulation, and tutorial.
- provide graphics capabilities and graphics editors.
- provide sound or speech synthesis capabilities and appropriate editors.
- provide structural features such as skip backward and forward routines.
- provide windows or split-screen effects.
- provide a variety of screen output formats (alphabets, fonts, letter sizes, etc.).
The ABC Authoring System

In this study the CAI lesson was developed using an authoring system called ABC. The ABC is an object-oriented programming system which was developed at Iowa State University for development of instructional applications. The ABC has a wide variety of capabilities that meet the instructional principles discussed previously.

Basically, the ABC lesson is an electronics Manual consisting of pages that can be linked or arranged together. Every page consists of figures which can be formed by shapes and an optional behavior. The shapes including text, polygons, buttons, arcs, etc., have a unique set of visual settings which may be changed. Figure 1 shows a blank page of the ABC. This page always appears first every time the ABC authoring system is opened, therefore, this page can be used as a title page (Boysen, 1994).

To make the shapes active, they may be assigned to optional behaviors such as quiz, link, judge, audio, movie, etc. Link behavior is one example of over 18 behaviors which can be assigned to a figure. Others include judging answers, playing audio or video clips, presenting quizzes and slide shows and many others, and the list is growing.

According to the ABC users reference guide (The Computer Supported Learning Group, 1994), the ABC uses three managers to help users design a manual. These are Manual Manager, Page Manager, and Bitmap Manager. First, the Manual Manager help users to add, delete and modify pages in the manual. Second, the Page Manager is used to add, delete and edit figures on a page by altering both their settings and their behavior. Third, the Bitmap Manager is used to create, design, and organize bitmaps.
Figure 1. A page of the ABC authoring system
By clicking on the EDIT button, the manual will show a Page Manager window and the manual is in the edit mode. Figure 2 shows a Page Manager window. The pull down menus that can be accessed from the Page Manager are Page menu, Figure menu, and Options menu.

These menus are as follows:

1. The Page menu has five choices including Redraw, Reset, Back Color, Annotate, and Undo.

2. The Figure menu has nine different choices including Add, Copy, Delete, Paste, Shuffle, Separate, Center, Undo, and Unbehave.

3. The Options menu has seven choices that can be expanded further. They are Color, Font, Fill, Line, Clipboard, Bitmap, and Spacing.

Figure 2. The Page Manager window
A variety of shapes are available from the Page Manager to design the text and graphics on the pages in a manual. Some of them are Arc, Axis, Backpage, Button, Editor, Icon, Messagewin, Painting, Polygon, Rectangle, Regpoly, Table, and Text. Each of these shapes has a unique set of visual settings which may be changed. Besides setting to different appearances, a shape can be assigned to a certain behavior to make it active.

When the manual is in the edit mode (a Page Manager is shown) a figure can be assigned to a behavior that makes it active. The ABC has eighteen different kinds of behaviors. These behaviors are (The Computer Supported Learning Group, 1994):

1. **Audio**: A figure with audio behavior will play an audio file when clicked on. A dialog box called Audio will appear when applying this behavior. In this box one has to enter the audio file and specify the starting time and length as appropriate.

2. **Check**: Check behavior is used to display a checkmark (\(\checkmark\)) next to a figure which has been clicked on by the user. A dialog box will appear when applying this behavior.

3. **Click**: A method or script will execute whenever a figure with click behavior is clicked on. One can specify a method for either a single or double click. Method is a term in ABC authoring system for a function in C language and for a procedure in Pascal. A method defines how an operation is performed. The ABC commands are typed in the method editor and compiled.

4. **Command**: The specified system command will be executed when the figure with Command behavior is clicked on.
5. **Definition**: Definition behavior is used to popup some text (e.g., definition of a word) when a figure is clicked on.

6. **Drag**: A figure with drag behavior will execute separate methods when the mouse button is pressed, moved or released on the figure. One has to click on the desired method button to edit the method.

7. **Judge**: Normally, judge behavior is associated with an editor figure. When the user presses RETURN, judge will compare the user's text with the answers. If an answer matches, the associated method will be executed.

8. **Link**: A figure with link behavior will show another page when the figure is clicked on.

9. **Movie**: Movie behavior will play an audio file and/or video file. Frame timing can be specified for timed slides.

10. **Path**: A figure with path behavior will follow the path specified by the Points. The points where a figure will go can be entered in the Points editor.

11. **Popup**: When a figure with popup behavior is clicked on, another figure will be displayed when the mouse button is depressed, and erased when the button is released.

12. **Quiz**: Quiz behavior will present a list of quiz questions. Each question is a page that has figures on it with Score behavior. Quiz will keep track of the score for each question. One has to enter the list of question pages or a folder of questions in the editor. The quiz questions will be presented in the order listed unless Randomize is selected. Normally, Quiz will show the next question after the current question is answered. However, in Review mode, the Wrong method will run if an answer is wrong. The Done method is run at the completion of the quiz.
13. **Radiocheck:** Radiocheck behavior is applied to a group of figures. It will allow only one of the figures to display a checkmark (✓).

14. **Reset:** There are times when a figure is sent a Reset message. It occurs when one is preparing a page for use by users or before a quiz page is displayed. One may supply a method to execute when this occurs. This can be useful if there is a page that displays a randomly generated question.

15. **Score:** Score behavior is used to give a numeric score when a figure is clicked on. The score is sent to the Manual Manager which is currently administering a quiz. The score is recorded for that page. If the score is greater than 0, it is considered a correct answer.

16. **Slidecontrol:** Once a slide show is started, when a figure with slideshow behavior is clicked on, the slide show can be controlled from any page by creating figures with Slidecontrol behavior. One can choose to move to the next, previous, first, or last slide; and stop, start or restart the slide show or return to the page which has the slideshow behavior.

17. **Slideshow:** Slideshow can be used to present a sequence of slides (i.e., pages). The page names need to be specified in the editor provided.

18. **Toggle:** A figure with toggle behavior will alternate between displaying and hiding a checkmark (✓) each time it is clicked on.

**Summary**

Microcomputers have a great potential for use in the delivery of instruction. Of all the instructional technologies available, microcomputers have the most relevance for preparing students for their future work environments.

Most of the current research on computer-assisted instruction effectiveness
approaches the problem by comparing this new instructional media to traditional media.

Generally, some findings showed that CAI usually has positive effects on students, and in some instances, no effect. However, these effects are not the same for all types of CAI, across all subject matter, or all grade levels. Development a CAI lesson for a special topic and students need to be further investigated.
CHAPTER III. METHODOLOGY

This chapter describes the methodology used to examine the research problems. Sections included in this chapter are: Research Design and Procedures, Subjects, Data Collection, Instrument, and Data Analysis.

Research Design and Procedures

As stated in Chapter I, Introduction, the purpose of this study was twofold. The first objective was to design and develop a computer-assisted instruction (CAI) lesson using the ABC authoring system which could be used for teaching basic electronics. The second objective was to evaluate some aspects of the lesson by investigating the students' perceptions after completing the lesson and by viewing videotape of the students who were learning the lesson. Therefore, this section is divided into two subsections: CAI lesson development, and CAI lesson evaluation.

CAI lesson development

The development of the CAI lesson followed several steps that are quite similar to some components of the Instructional Systems Development (ISD) approach. The steps followed to design and develop the CAI lesson using the authoring language ABC for teaching basic electronics were to:

1. define the objectives of the CAI lesson;
2. identify some concepts in basic electronics;
3. review the authoring language ABC;
4. design the presentation techniques;
5. develop the CAI lesson;
6. make the lesson available for public;
7. have the expert review the lesson; and
8. perform some revisions.

**CAI lesson evaluation**

In evaluating the performance of the CAI lesson, some undergraduate students were asked to participate voluntarily. This part of the study tended to be a qualitative research with the emphasis on the students' reactions to the CAI lesson by probing their attitudes as well as by examining their test results. According to Leach (1990) qualitative research differs from quantitative research which deals with large samples and asks what were the effects (by studying the quantity of behavior). Qualitative research involves an in-depth investigation of a small sample to determine why the effect occurred (by studying the quality of behavior).

A small, purposeful sample group was most amenable to this qualitative investigation. The design did not address issues that could be quantified, and findings were not statistically generalized to a larger population. The procedures for evaluation of the CAI lesson were to:

1. obtain approval from the University Human Subjects Review Committee;
2. arrange for data collection;
3. administer a pretest;
4. administer the CAI lesson and videotape the subjects;
5. administer the questionnaires and a post-test; and
6. analyze the data.
Subjects

The subjects of this study were five undergraduate students at Iowa State University. They were selected purposively to participate in the study and were given incentive. The subjects were not taking and had not taken electronic class.

Data Collection

In this research five undergraduate students were studied. Data were collected from a combination of questionnaires, achievement tests, and observations of videotapes. After the subjects submitted a signed consent form indicating their agreement to participate in the research, the investigator made arrangement for data collection.

One week before accessing the CAI lesson, a pretest was given to the subjects. During the study the subjects were assumed not to have learned the material from any other resources because they were not taking any electronics class. In addition, by giving the pretest one week before, the effect of the pretesting on a post-test would be minimized.

It took approximately six hours to complete the lesson. The lesson was divided into three sessions of two hours each. These three sessions were conducted within a time frame of one week. The subjects were videotaped while learning the lesson, so that their steps and reactions in completing the lesson could be recorded. The focus of the videotaping was primarily on the computer terminal (monitor), so that the observer could see how the subjects learned the lesson. One videotape recorder shot two subjects simultaneously, so that the details could be observed when playing back the tape.
After completing the lesson, each of the five students were given questionnaires concerning their attitudes toward the CAI lesson and a post-test to measure their achievement on basic electronics.

**Instrument**

Questionnaires and tests were the primary data collection methods besides observations. The questionnaires (see Appendix B) consisted of three sections: (a) general; (b) background in computer experience; (c) the CAI lesson evaluation.

The first section (a) contained some questions designed to collect demographic data of the research subjects. This general section consisted of four items related to the subjects' personal information. The second section (b) consisted of eight items which were used to obtain some information about the participants' background and experiences in computers. These two sections of the instrument were developed by the investigator based on the literature review and suggestions made by the present researcher's committee.

The last section of the questionnaires was the CAI Lesson Evaluation (c). This instrument, developed by the National Center for Research in Vocational Education, evaluated four aspects of the CAI lesson: (1) subject matter, (2) presentation, (3) student interaction, and (4) program interaction. The subject matter subsection (part 1) was supposed to measure whether the content of the CAI lesson had educational value. The next subsection presentation (part 2) was used to check if the package program was free of malfunctions. The student interaction subsection (part 3) examined if the students were actively involved
with the program. The last subsection program interaction (part 4) was used to see if the feedback is effectively employed in the CAI lesson.

In order to measure the level of knowledge in basic electronics before learning the CAI lesson and the level of achievement after completing it, a pretest and a post-test were given to the subjects. The tests were developed by the investigator and reviewed by an electronics expert, the major professor. They consisted of fifty questions and covered five topics extracted from the CAI lesson. The complete test can be seen in Appendix C.

To analyze the videotapes, the observational questions (see Appendix D), consisting of ten questions, were used. This checklist would measure some aspects of the CAI lesson that could not be revealed by the questionnaires.

**Data Analysis**

Data collected from the questionnaires were coded and categorized. Demographic data obtained from the first two sections of the questionnaires were grouped and analyzed. The results would be presented efficiently by using texts instead of tables because the number of subjects was small enough.

The students' responses to the Likert-type items of the CAI lesson evaluation, the third section of the questionnaire, were analyzed by using descriptive statistics. In order to summarize a typical value of the responses to each item, measures of central tendency and variability were used. The best way to measure the central tendency for the ordinal data ranging from strongly disagree (1) to strongly agree (5) is by using the median (Agresti, 1979; Ary, 1990; Guilford & Fruchter, 1973) and to measure the variability by using quartile deviation (Ary, 1990). The median (Md.) is defined as the measurement that
falls in the middle when the sample measurements are ordered according to their magnitudes. The quartile deviation (Qd.), also called *semi-interquartile range*, is one-half the difference between the upper quartile (the 75th percentile) and lower quartile (the 25th percentile) in a distribution.

Answers to the achievement tests (pretest and post-test) consisting of fifty questions were assessed for each student. To summarize the results, the mean pretest and post-test scores as well as the standard deviation were calculated.

Finally, the videotapes were observed and the observational question check list was completed. The data were categorized and summarized in tables.
CHAPTER IV. RESULTS AND DISCUSSION

This chapter presents and discusses the results of the study which are related to the research questions stated in the introduction. The first section of this chapter will answer the first question and the second section will answer the last two questions.

Development of the CAI Lesson

The first research question stated in Chapter I was "How can the ABC authoring system be used to design and develop a CAI program for teaching basic electronics?" Following are the results dealing with the research question.

Objectives of the CAI lesson

The first step in designing the CAI lesson was to define what were the objectives that had to be achieved. These objectives must be stated clearly in the lesson, so that the users know what was expected of them after completing the lesson.

There were two types of objectives developed in this lesson. The first one was a general objective. This type of objective appeared in the introduction page of the lesson so that the users could access it at the beginning of their session. The second one was a specific objective. This objective appeared at the beginning of each section throughout the lesson.

The general objective of the CAI lesson was to help students learn basic electronics with an emphasis on understanding and applying basic concepts. The specific objectives were as follows:
Topic 1: Basic Quantities
- After completing section 1 (Current) the students will be able to:
  1. state what an electron is.
  2. define current.
  3. calculate current.
- After completing section 2 (Voltage) the students will be able to:
  1. define voltage.
  2. identify various types of voltage sources.
  3. calculate voltage.
- After completing section 3 (Resistance) the students will be able to:
  1. define resistance.
  2. identify types of fixed and variable resistors.
  3. determine resistance value by color code.
- After completing section 4 (The electric circuit) the students will be able to:
  1. describe a basic electric circuit.
  2. identify closed and open circuits.
  3. understand short circuits.
- After completing section 5 (Measurement) the students will be able to:
  1. identify ammeters, voltmeters, and ohmmeters.
  2. measure current, voltage, and resistance.
  3. identify multimeters.

Topic 2: Ohm's Law
- After completing section 1 (Ohm's law concept) the students will be able to:
  1. define Ohm's law.
  2. understand Ohm's law concept.
3. state Ohm's law formula.

- After completing section 2 (Calculating current) the students will be able to:
  1. apply Ohm's law to determine current.
  2. calculate current with larger units of resistance and voltage.

- After completing section 3 (Calculating voltage) the students will be able to:
  1. apply Ohm's law to determine voltage.
  2. calculate voltage with larger units of resistance and smaller units of current.

- After completing section 4 (Calculating resistance) the students will be able to:
  1. apply Ohm's law to determine resistance.
  2. calculate resistance with smaller units of current.

- After completing section 5 (Power) the students will be able to:
  1. define power.
  2. apply Ohm's law to determine power.
  3. state formulas for power.

Topic 3: Series Circuits

- After completing section 1 (Characteristics of series circuits) the students will be able to:
  1. identify a series circuit.
  2. determine the total resistance of a series circuit.
  3. determine the current in a series circuit.
  4. connect voltage sources in series.

- After completing section 2 (Applying Ohm's law) the students will be able to:
  applying ohm's law to find the current, voltage, and resistance in a series circuit.
- After completing section 3 (Kirchhoff's voltage law) the students will be able to:
  1. define Kirchhoff's voltage law.
  2. apply Kirchhoff's voltage law to perform some calculations in a series circuit.

- After completing section 4 (Voltage dividers) the students will be able to:
  1. understand the principle of voltage dividers.
  2. state voltage divider formulas.
  3. use voltage divider principles to perform some calculations.

Topic 4: Parallel Circuits

- After completing section 1 (Characteristics of parallel circuits) the students will be able to:
  1. identify a parallel circuit.
  2. determine the total resistance of a parallel circuit.
  3. determine the voltage in a parallel circuit.

- After completing section 2 (Applying ohm's law) the students will be able to apply Ohm's law to find the current, voltage, and resistance in a parallel circuit.

- After completing section 3 (Kirchhoff's current law) the students will be able to:
  1. define Kirchhoff's current law.
  2. apply Kirchhoff's current law to perform some calculations in a parallel circuit.

- After completing section 4 (Current dividers) the students will be able to:
  1. understand the principle of current dividers.
  2. state current divider formulas.
  3. use current divider principle to perform some calculations.
Topic 5: **Series-Parallel Circuits**

- After completing section 1 (Identifying series-parallel circuits) the students will be able to identify series and parallel portions of a series-parallel circuit and recognize the relationship of all resistance.

- After completing section 2 (Analysis of series-parallel circuits) the students will be able to:
  1. determine the total resistance of a series-parallel circuit.
  2. determine the currents and voltages in a series-parallel circuit.

- After completing section 3 (Loaded voltage dividers) the students will be able to:
  1. determine how resistive load will affect voltage divider circuits.
  2. recognize and determine the effect of a voltmeter on measuring voltage.

- After completing section 4 (The superposition theorem) the students will be able to:
  1. state the definition of the superposition theorem.
  2. apply the superposition method to evaluate circuits with more than one source.

- After completing section 5 (Thevenin's theorem) the students will be able to:
  1. state the definition of Thevenin's theorem.
  2. understand the meaning of circuit equivalency.
  3. apply Thevenin's theorem to simplify complex circuits.

- After completing section 6 (Norton's circuits) the students will be able to:
  1. state the definition of Norton's theorem.
  2. apply Norton's theorem to simplify complex circuits.
**Presentation techniques**

The presentation technique of this CAI lesson was based on the tutorial model where the information was presented first and then followed by some questions for practice in using and applying the new information. The tutorial program presents information, asks a question, accepts the learner's response, and provides feedback appropriate for the response (Lilie et al., 1989). Figure 3 shows the basic tutorial model on which this lesson was based.

![Diagram of basic tutorial model](image)

**Figure 3. Basic tutorial model**
The overall organization of the lesson is shown in Figure 4. This figure represents the lesson structures including contents and pathways. In order to simplify the figure, the structures under topics Ohm's Law, Series Circuits, Parallel Circuits, and Series-Parallel Circuits are not shown in details. They are represented by dotted boxes. Even in the Basic Quantities topic, only sections Current and Quiz are figured in details.

The CAI lesson titled "electronics" contains 229 pages including 110 pages of materials and 119 pages of exercises and quizzes. It can be accessed from the Project Vincent terminal by typing the following commands after the "vincent%" prompt:

1. vincent% add abc <RETURN>
2. vincent% abcinit <RETURN> (for first time users only)
3. vincent% lesson electronics <RETURN>

The CAI lesson is designed to give the users flexibility in controlling the sequence of the material. From every page of the lesson they may go forward, backward or even skip to the menu easily. However, from exercises and quizzes the page automatically advances to the next page after the users answer the question, except click on the Cross Reference button. The first page of the lesson, title page, also automatically appear when the users open the lesson. Figure 5 shows the title page.

To move from the title page to the next page, the users must click on the Start button available at the lower corner of the page. This button is assigned to a link behavior where the next page is the Main Menu page. This page is shown in Figure 6.
Figure 4. The organization of the CAI lesson
Figure 5. The title page of the lesson
Click on one of these:

1. Introduction
2. Basic Quantities
3. Ohm’s Law
4. Series Circuits
5. Parallel Circuits
6. Series-Parallel Circuits

Press the number to see the contents

Cross Reference

Figure 6. Main Menu page
From the Main Menu one can go to an introduction page which contains information about the purpose of the lesson and some directions for the users and to five difference topics covered in the lesson by clicking on the letters. However, the users may press (click on and hold) the number at front of the letters to see the contents of the topic on the popup mode. These can be done by assigning two different behaviors to the number and the letter, although they seem at the same line (see Figure 6). For example, the second choice is "2. Basic Quantities"; the number "2" is assigned to a popup behavior and the letters "Basic Quantities" is assigned to a link behavior. Figure 7 shows the dialog box for a link behavior. The check mark is applied in this box, so that when the "Basic Quantities" is clicked on, a √ appears in front of it.

![Link dialog box](image)

Figure 7. Dialog box of link behavior
From the Basic Quantities menu page one can go to six different sections including Current, Voltage, Resistance, The Electric Circuits, and Measurements and Quiz by clicking on the letters. However, a different effect can be seen by pressing (clicking on and holding) the number. While pressing the number the users can see the objectives of the section on the popup mode.

For example when one is pressing the number 3 (choice number 3), the objectives of section Resistance will appear on the lower part of the page with popup mode and when we release it the objectives will disappear (see Figure 8). This is because the number 3 was assigned to a popup behavior. By doing this the screen space can be saved.

However, when one is clicking on the letter part of the choice 3 that is the word "Resistance", the first page of the Resistance material will appear. This is because the word "Resistance" was assigned to a link behavior. A check mark will also appear in the front of the word "Resistance". This check mark will not disappear until the reset button is clicked on.

The section Resistance consists of nine pages including five pages for presenting material, three pages for presenting exercises, and one page for presenting achievement report and answers to the exercises. In this section the material covers main points of resistance including definition, Ohm, resistors, fixed resistors, resistor color codes, and examples. While in the material pages one can go forward, backward or even go to the menu to discontinue the section. The users have a great flexibility to control the sequence of the material. One example of the page is shown in Figure 9.
Basic Quantities

Click on one of these:

1. Current
2. Voltage
3. Resistance
4. The Electric Circuits
5. Measurements
6. Quiz

Press the number to see the objectives

After completing this section, you will be able to:
- define resistance.
- identify types of fixed and variable resistors.
- determine resistance value by color code.

Figure 8. The Basic Quantities menu with a popup figure
5. Resistor Color Code

Fixed resistors with value tolerances of 5%, 10%, or 100% are color coded with four bands to indicate the resistance value and the tolerance.

Figure below shows this color-code band system.

<table>
<thead>
<tr>
<th>Resistance values, first three bands.</th>
<th>Tolerance, fourth band</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Black</td>
<td>5% Gold</td>
</tr>
<tr>
<td>1 Brown</td>
<td>10% Silver</td>
</tr>
<tr>
<td>2 Red</td>
<td>20% No band</td>
</tr>
<tr>
<td>3 Orange</td>
<td></td>
</tr>
<tr>
<td>4 Yellow</td>
<td></td>
</tr>
<tr>
<td>5 Green</td>
<td></td>
</tr>
<tr>
<td>6 Blue</td>
<td></td>
</tr>
<tr>
<td>7 Violet</td>
<td></td>
</tr>
<tr>
<td>8 Gray</td>
<td></td>
</tr>
<tr>
<td>9 White</td>
<td></td>
</tr>
</tbody>
</table>

Figure 9. An example of the resistance page
Once one is clicking on the exercise button at the end of the material pages, the lesson will advance through all exercises. However, while doing the exercises the users may click on a Cross Reference button to see a full page of the cross reference on a separate page. This reference features all materials covered in the lesson. The users may click one of the pages covered in the lesson they want to see while they are doing the exercises. This will help the students when they are having some difficulties in doing the exercises. Figure 10 shows the Cross Reference page.

**Programming the CAI lesson**

In order to use the capabilities of the ABC authoring systems maximally, some programming in designing a lesson is needed. The programming is important when the lesson deals with judging, scoring, and quiz. In this CAI lesson there is an exercise consisting of three questions in every section and a quiz consisting of ten questions in each topic. These exercises and quizzes are similar in terms of programming in ABC authoring systems. Those different names are merely for use under sections and the other under topics.

At the end of each material presentation, under section, there is a button called Exercise assigned to a quiz behavior. By clicking on this button the users will advance to the first of three questions. When the users answer the first question the next question automatically appears and so on. Every question is displayed on a page. The ABC authoring system does this because the list of the questions is entered in the quiz editor (see Figure 11).
### Basic Electronics: DC Circuits

#### Cross References

**Basic Quantities**
- **Current**
  - Definition/Unit of Charge/Formula: Ampere/Example/Exercise
- **Voltage**
  - Definition/Formula/Model: Example/Voltage Sources/Exercise
- **Resistance**
  - Def/Ohm/Resistors: Fixed Color Example Variable/Exercise
- **Electric Circuits**
  - Elect Circuits/Closed Cir: Open/Short Cir/Exercise
- **Measurement**
  - M. Current M. Voltage M. Resistance Multimeter/Exercise

**Ohm’s Law**
- **Ohm’s Law Concept**
  - Definition Formulas/Exercise
- **Calculating Current**
  - Calculating Current Larger P: Larger V/Exercise
- **Calculating Voltage**
  - Calculating Voltage Larger P: Smaller C/Exercise
- **Calculating Resistance**
  - Calculating Resistance Smaller C/Exercise

**Series Circuits**
- **Characteristics**
  - Series Total Series P: Total Series V:source/Exercise
- **Applying Ohm’s Law**
  - Problem 1 Problem 2 Problem 3/Exercise
- **Kirchhoff’s Voltage Law**
  - Def. Example/Exemplar/Exemplar: Example/Exercise

**Parallel Circuits**
- **Characteristics**
  - Parallel Total T: Total P: Equal P: Par. V/Exercise
- **Applying Ohm’s Law**
  - Problem 1 Problem 2 Problem 3/Exercise
- **Kirchhoff’s Current Law**
  - Definition Example/Exercise

**Series-Parallel Circuits**
- **Characteristics**
  - Series-Parallel P: Series-Parallel T: Series-Parallel V:source/Exercise
- **Analysis of S-P Circuits**
  - Example 1 Example 2 Example 3/Exercise
- **Loaded Voltage Dividers**
  - Figures Example 1 Example 2/Exercise

**Thevenin’s Theorem**
- **Thevenin’s Theorem**
  - Def. Circuit equiv. Method Example/Exercise

**Norton’s Theorem**
- **Norton’s Theorem**
  - Def. Circuit equiv. Method Example/Exercise

**Menu**
- Figure 10. The Cross Reference page
Figure 11. The Quiz editor for the exercise

When all questions have been answered, the quiz will execute the done method. In this exercise it will show a score obtained and a message concerning what the users should do next on a page containing answers to the exercises.

The done method for this exercise is as follows:

```plaintext
doneFor theManager:Manualman
  { a → theQuiz totalscore.
    b → Text newText [a asString].
    b foreground 4.
```
aFont → Font typeface "times" style #bold pointSize 24.
bsetFontTo aFont.
c → Text newText ["YOUR SCORE:"].
c foreground 4.
c setFontTo aFont.
d → Text newText ["VERY GOOD ! !: Go to the next Section"].
d setFontTo aFont.
e → Text newText ["YOU MAY REVIEW THIS SECTION !!"].
e setFontTo aFont.
(a < 3) then
{ d foreground 101.
  e foreground 83.
}.
(a > 2) then
{ d foreground 5.
  e foreground 101.
}.
theManager showPage "BQ-cu3".
me draw c at (300 @ 100).
me draw b at (800 @ 100).
me draw d at (30 @ 155).
me draw e at (25 @ 200).
}

If the users answer all three questions correctly, the message that will appear is:

"YOUR SCORE : 3"
"VERY GOOD !!: Go to the next section"

When only one or two answers are correct, the message is:

"YOUR SCORE : 1"

"YOU MAY REVIEW THIS SECTION !!"

The done method for the quiz consisting of ten questions is as follows.

doneFor theManager:Manualman

{ a → theQuiz totalscore.
  b → Text newText [a asString].
  b foreground 4.
  aFont → Font typeface "times" style #bold pointSize 24.
  b setFontTo aFont.
  c → Text newText ["YOUR SCORE:"].
  c foreground 4.
  c setFontTo aFont.
  d → Text newText ["VERY GOOD !!: Go to the next Topic"].
  d setFontTo aFont.
  e → Text newText ["YOU MAY REVIEW THIS TOPIC !!"].
  e setFontTo aFont.
  f → Text newText ["EXCELLENT !!: Go to the next Topic"].
  f setFontTo aFont.
  g → Text newText ["O K !!: You may go to the next Topic"].
  g setFontTo aFont.
  (a > 9) then
  { d foreground 101.
  e foreground 101.
(a > 8) then
{ (a < 10) then
    { f foreground 101.
      e foreground 101.
      g foreground 101.
      d foreground 3.
    }.
}.

(a > 6) then
{ (a < 9) then
    { f foreground 101.
      e foreground 101.
      d foreground 101.
      g foreground 3.
    }.
}.

(a > 7) then
{ f foreground 101.
  g foreground 101.
  d foreground 101.
  e foreground 2.
}.
When the users can answer all the questions correctly, a message will appear:

"YOUR SCORE: 10"
"EXCELLENT !!: Go to the next Topic"

When there are nine correct answers, the message is:

"YOUR SCORE: 9"
"VERY GOOD !!: Go to the next Topic"

If the correct answers are 7 or 8, the message is:

"YOUR SCORE: 7"
"O K !!: You may go to the next Topic"

When the users can answer only six or less, the message is:

"YOUR SCORE: 5"
"YOU MAY REVIEW THIS TOPIC"

Each question in the ABC authoring systems is designed on a page like any other text or graphic. This CAI lesson has three types of questions; (1) multiple choice; (2) completion; and (3) drag and drop. Each of these types of questions needs to be assigned to different behavior and method. In the multiple choice question each possible answer represents an independent figure
which is assigned to a click behavior. By assigning this behavior it is possible to give either positive or negative feedback in addition to an appropriate score after choosing the answer. Positive feedback is given if the user chooses the correct answer and negative feedback for choosing the wrong answer. Figure 12 and 13 show message boxes for positive and negative feedback.

![Figure 12. A message box for positive feedback](image)

![Figure 13. A message box for negative feedback](image)
The figure that is supposed to be a correct answer is assigned to the click behavior with the method as follows:

```plaintext
click theManager:Manualman with anEvent:Event

{ db \rightarrow theManager report "**********\n* RIGHT *\n**********":
  myTask wait 1000.
  db delete.
  theQuiz score 1 for theManager.
}
```

and the figure that is supposed to be a wrong answer is assigned to the click behavior with the method as follows.

```plaintext
click theManager:Manualman with anEvent:Event

{ db \rightarrow theManager report "**********\n* WRONG *\n**********":
  myTask wait 1000.
  db delete.
  theQuiz score 1 for theManager.
}
```

The second type of question used in this CAI lesson is completion. This type of question asks the user to enter a response into an editor figure. This figure is assigned to a judge behavior. In the judge dialog box (see Figure 14) all possible answers are supplied and a respond method for each answer is composed. By assigning the figure to this behavior it is possible to enforce capitalization, punctuation, spelling, word order, and word count toward the user's answer.
After the user has entered a response and hit a return key, the ABC authoring system will compare the response with the first answer supplied in the judge dialog box. If they match, the response method will execute. If not, the user's response will be compared to the next answer. This matching process will continue until a response is matched or the default answer is encountered, in which case the default response method will be executed. The response method is just similar to the click method described previously.

The third type of question is a "drag and drop" question. This question is found in section Measurement under the topic Basic Quantities. In this question there is an electrical circuit that has a missing component. For choices, below the circuit are some components, one of which is supposed to be the correct part of the circuit. The user must chooses and drags the component, and then drops it in the correct place where it is supposed to be. Each of the components is
assigned to a drag behavior with the button release method. The method for the correct figure is as follows:

```plaintext
buttonRelease theManager:Manualman with anEvent:Event
    { p -> me getFigure "amp".
        k -> p's form.
        x -> k's origin's x.
        y -> k's origin's y.
        (x < 560) then
            (x > 520) then
                (y < 330) then
                    (y > 300) then
                        { db -> theManager report "*********
                            myTask wait 1000.
                            db delete.
                            theQuiz score 1 for theManager.
                        }.
                }.
            }.
        }.
    }.
```

The method for the wrong answer is as follows:

```plaintext
buttonRelease theManager:Manualman with anEvent:Event
    { p -> me getFigure "volt".
        k -> p's form.
        x -> k's origin's x.
```
y \rightarrow k's \text{origin's } y.

(x < 560) \text{ then } 
\{ (x > 520) \text{ then } 
\{ (y < 330) \text{ then } 
\{ (y > 300) \text{ then } 
  \{ db \rightarrow \text{theManager report } "\text{*******n}\text{WRONG }\text{n*********".} 
  \text{ myTask wait 1000.} 
  \text{db delete.} 
  \text{theQuiz score 0 for theManager.} 
  \}, 
  \}, 
  \}, 
  \}, 
\}

The Cross Reference, as shown in Figure 10, can be accessed from the Main Menu and from every exercise and quiz pages. Because the Cross Reference page will appear beside the main page from where it is launched, it uses a click behavior instead of a link behavior. A click method is used to open the Cross Reference page.

  \text{click theManager:Manualman with anEvent:Event} 
  \{ \text{theManager showPage } "\text{CR}" \text{ in } "\text{Reference}" \text{ at #right.} 
  \}

The Cross Reference page contains menus so that all materials being presented in the CAI lesson can be opened from this page. Therefore, it has button figures for as many pages as covered for all material in the lesson. Each
of the button figures represents a page of material. Every button figure is assigned to a click behavior with an appropriate method to open a particular page. The method is as follows:

```
  click theManager:Manualman with anEvent:Event
    { theManager showPage "OL-po2" in "Reference" at #right.
      p → theManual at "clipboard".
      k → p's display at "caption".
      (k's form movex 30 movy 1290) writeMode #overlay.
      k drawIn theManager's theWindow.
    }
```

**Evaluation the CAI Lesson**

The second and third research questions as stated in Chapter I were "What were the students' perceptions about the CAI lesson concerning the following aspects: (a) subject matter, (b) presentation, (c) student interaction, and (d) program interaction?" and "Did the students learn anything from the lesson?" In order to answer these questions, a qualitative research was carried out as described in the chapter methodology. This section will explain the results.

**Demographic data**

The second part of this study involved five undergraduate students at Iowa State University as subjects, including four males and one female who participated voluntarily. The requirements for each of the subjects were: (a) they were not taking and had not taken any college-level electronics class; and (b) they had a Project Vincent account. It was assumed that, during the study,
the students were not to learn any electronics material from any other resources except from the CAI lesson.

Two of the subjects were majoring in computer science and the other three were from pre-business, economics, and mathematics. All of the subjects had taken a college-level course in computer literacy and/or computer programming. Two students were majoring in computer science and described their knowledge of the computer as intermediate, while the others were beginners. However, only one of the five students had his/her own personal computer at home. Mostly, they used a computer at the Computation Center or within the department.

The subjects majoring in computer science used a computer almost every day while the others used one only a few days each week. The software packages they have used were word processing, spreadsheet, and programming. None of the five students had ever used an educational program such as the CAI lesson.

**Student perceptions about the CAI lesson**

The third section of the questionnaire was supposed to reveal the students' perceptions about the CAI lesson. It consists of four subsections: (a) subject matter; (b) presentation; (c) student interaction; and (d) program interaction. The median (Md.) and quartile deviation (Qd.) which were described in the chapter methodology, with N = 5 were calculated for each item. The results are presented in Table 1 through Table 4. The range is as follows: (1) strongly disagree; (2) disagree; (3) neutral; (4) agree; (5) strongly agree.
Table 1. The CAI lesson evaluation in aspect of subject matter

<table>
<thead>
<tr>
<th>Items evaluated</th>
<th>Md</th>
<th>Qd</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Objectives are stated clearly.</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>2. Topics are logically presented.</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>3. Subject matter is easy to understand.</td>
<td>4</td>
<td>0.5</td>
</tr>
<tr>
<td>4. Examples are clear and helpful.</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>5. Answers to the exercises and quizzes are helpful.</td>
<td>4</td>
<td>0.5</td>
</tr>
<tr>
<td>6. Question items are clearly stated.</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>7. Subject matter is accurate.</td>
<td>5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 2. The CAI lesson evaluation in aspect of presentation

<table>
<thead>
<tr>
<th>Items evaluated</th>
<th>Md</th>
<th>Qd</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Program is free of technical problems.</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>2. Information on the screen is easy to read.</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>3. Program is free of spelling and grammatical errors.</td>
<td>4</td>
<td>0.5</td>
</tr>
<tr>
<td>4. Program is self instructed.</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>5. Color increases the instructional value of the program.</td>
<td>4</td>
<td>0.5</td>
</tr>
<tr>
<td>6. Graphics increase the instructional value of the program.</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>7. Feedback on the exercises and quizzes is helpful.</td>
<td>4</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Table 3. The CAI lesson evaluation in aspect of student interaction

<table>
<thead>
<tr>
<th>Items evaluated</th>
<th>Md</th>
<th>Qd</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The student is actively involved in the program.</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>2. The student controls the pace of the program.</td>
<td>4</td>
<td>0.5</td>
</tr>
<tr>
<td>3. The student can access the menu to change topics.</td>
<td>4</td>
<td>0.5</td>
</tr>
<tr>
<td>4. The student can go forward/backward through topics.</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>5. The student can exit any time and from any page.</td>
<td>4</td>
<td>0.5</td>
</tr>
<tr>
<td>6. The student can control the sequence of the topics.</td>
<td>5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 4. The CAI lesson evaluation in aspect of program interaction

<table>
<thead>
<tr>
<th>Items evaluated</th>
<th>Md</th>
<th>Qd</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Feedback is immediate.</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>2. Feedback in non threatening.</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>3. Program gives answers to the exercises and quizzes.</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>4. Program has the ability to suggest to branch / loop depending upon student's performance.</td>
<td>4</td>
<td>0.5</td>
</tr>
</tbody>
</table>
**Student achievement**

In order to measure how much basic electronics the students learned from the CAI lesson, a pretest was administered one week before the study began and after completing the lesson they were given a post-test. The pretest/post-test consisted of fifty questions, including ten questions on each topic. The results are presented in Table 5.

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Pretest scores</th>
<th>Post-test scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 1</td>
<td>2</td>
<td>27</td>
</tr>
<tr>
<td>Student 2</td>
<td>5</td>
<td>35</td>
</tr>
<tr>
<td>Student 3</td>
<td>3</td>
<td>36</td>
</tr>
<tr>
<td>Student 4</td>
<td>9</td>
<td>40</td>
</tr>
<tr>
<td>Student 5</td>
<td>6</td>
<td>37</td>
</tr>
</tbody>
</table>

Mean = 5; SD = 2.7  
Mean = 35; SD = 4.8

**Discussion**

Overall, the ABC authoring system as an authoring tool has a great variety of features that meet instructional principles for developing a CAI lesson for teaching electronics. Responses on the CAI lesson evaluation instrument showed that the students have highly positive attitudes toward some aspects of the lesson such as subject matter, presentation, student interaction, and program interaction. These results indicate that the students have good perceptions about this CAI lesson.
The level of achievement as measured by the post-test at the end of the study increased considerably when it was compared to the pretest scores. The effect of pretesting on the post-test scores may exist, but it was minimized by giving the pretest about two weeks before the post-test. In addition, the students who were selected had no background on electronics and were not enrolled in any electronics class. This assured the CAI lesson's contribution to the change in the students' knowledge would not be confounded.

The videotapes were analyzed according to the observational questions. The questions answered by the investigator while observing the subjects learning the CAI lesson through the videotapes would measure some aspects that could not be revealed by the questionnaires.

In the ABC authoring system each page of the lesson has some built-in buttons located at the top of the page. These buttons are "EXIT" for exiting the program, "SAVE" for saving the program, "HOME" for returning to the title page, "BACK" for going back to previous pages, "PRINT" for printing the current page, "HELP" for opening help menu, "MANUAL" for opening the Manual Manager window, and "EDIT" for editing the lesson. In the CAI lesson developed by the investigator, the MANUAL and EDIT buttons were omitted to avoid editing and copying by users. During the study the students did not open the HELP button and any other buttons at all except EXIT button at the end of the session.

One page of the lesson designed to be helpful is the Cross Reference page which is laid beside the originator page. From this Cross Reference page the users can access any pages in the lesson on the separate page. This selected page would be helpful while doing the exercises or quizzes. All the students were
observed to open the Cross Reference page. All the students also used a calculator, and scratch paper and a pencil during learning the lesson. The students were observed to select and complete all topics from the Main Menu, and all sections including exercises and quizzes.

The time allocated for completing each topic can be seen in Table 6.

Table 6. Allocation time for completing the CAI lesson

<table>
<thead>
<tr>
<th>Topic</th>
<th>Range allocated time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introduction</td>
<td>3 - 5 minutes</td>
</tr>
<tr>
<td>2. Basic Quantities</td>
<td>35 - 50 minutes</td>
</tr>
<tr>
<td>3. Ohm's Law</td>
<td>45 - 65 minutes</td>
</tr>
<tr>
<td>4. Series Circuits</td>
<td>45 - 65 minutes</td>
</tr>
<tr>
<td>5. Parallel Circuits</td>
<td>45 - 65 minutes</td>
</tr>
<tr>
<td>6. Series-Parallel Circuits</td>
<td>65 - 80 minutes</td>
</tr>
<tr>
<td>Total:</td>
<td>4.5 - 6 hours</td>
</tr>
</tbody>
</table>
CHAPTER V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary of the Study

This study was designed to develop a computer-assisted instruction (CAI) lesson using the ABC authoring system for teaching basic electronics and to examine its performance by exploring the students' perceptions after completing the lesson. The ABC is an object-oriented programming system which was designed at Iowa State University for development of instructional applications. The lesson is designed to help students learning basic electronics with an emphasis on understanding and applying basic concepts.

The lesson accessed on Project Vincent with a title of "electronics" covered some topics on DC Circuits: Basic Quantities, Ohm' Law, Series Circuits, Parallel Circuits, and Series-Parallel Circuits. The presentation technique of this CAI lesson is based on a tutorial model where the information is presented first and then followed by some questions for practice in using and applying the new information. An appropriate feedback would follow when the users answer the questions. The lesson contains 229 pages including 110 pages of materials and 119 pages of exercises and quizzes.

When the development of the lesson was completed, five undergraduate students at Iowa State University who were not taking an electronics class voluntarily agreed asked to access and learn the lesson. Before and after accessing the lesson, the students were given a pretest and post-test to measure their level of achievement. In addition, a set of questionnaires was given to obtain demographic data and, more importantly, to explore their perceptions.
and evaluations of the CAI lesson. The students were videotaped while learning the lesson to measure some aspects that could not be revealed by the questionnaires.

Responses to the Likert-type items of the CAI lesson evaluation were analyzed by calculating their medians and quartile deviations. In general, the measures for each item showed a highly favorable score, ranging from 4 to 5 in an ordinal scale of 1 to 5. The mean pretest score was 5 and the mean post-test score was 35, with standard deviations of 2.7 and 4.8, respectively. The total time needed to complete the lesson was approximately 4.5 to 6 hours.

Conclusions

From this study several conclusions can be drawn and are presented as follows:

1. The CAI lesson designed by using the ABC authoring system for teaching basic electronics covered some topics on DC Circuits such as Basic Quantities, Series Circuits, Parallel Circuits, Series-Parallel Circuits. The lesson entitled "electronics", consisting of 110 pages of materials and 119 pages of questions, can be accessed on Project Vincent.

2. The students had highly positive attitudes toward some aspects of the CAI lesson: subject matter, presentation, student interaction, and program interaction.

3. After learning the CAI lesson the students' level of achievement improved from a mean pretest score of 5 with standard deviation of 2.7 to a mean post-test score of 35 with standard deviation of 4.8.
4. In order to complete the CAI lesson, the students needed a total time of about 4.5 to 6 hours, with an average of one hour for each topic.

Recommendations

1. It is recommended that the CAI lesson should be evaluated further, either by a greater number of students who are to use the lesson or by electronics/instructional experts.

2. It is recommended that the same lesson be developed with different features throughout the lesson and to investigate the effects on the students' achievement.

3. It is recommended that a CAI lesson be developed for teaching any other subject matter by using the ABC authoring system.
REFERENCES


ACKNOWLEDGMENTS

I would like to express my appreciation and acknowledge my debt to several individuals who contributed to the completion of this research study. For guidance and support, I extend my gratitude to:

Dr. Larry L. Bradshaw - major professor

Dr. William G. Miller - committee member

Dr. Pete Boysen - committee member

Dr. John C. Dugger - chairman of the Department of Industrial Education and Technology

Ms. Pat Hahn - secretary of the Department of Industrial Education and Technology

Finally, I thank my wife and son for the love, encouragement, and support they have given me during my study.
APPENDIX A: HUMAN SUBJECTS COMMITTEE APPROVAL
Checklist for Attachments and Time Schedule

The following are attached (please check):

12. ☑️ Letter or written statement to subjects indicating clearly:
   a) purpose of the research
   b) the use of any identifier codes (names, #’s), how they will be used, and when they will be removed (see Item 17)
   c) an estimate of time needed for participation in the research and the place
   d) if applicable, location of the research activity
   e) how you will ensure confidentiality
   f) in a longitudinal study, note when and how you will contact subjects later
   g) participation is voluntary; nonparticipation will not affect evaluations of the subject

13. ☐ Consent form (if applicable)

14. ☐ Letter of approval for research from cooperating organizations or institutions (if applicable)

15. ☑️ Data-gathering instruments

16. Anticipated dates for contact with subjects:

<table>
<thead>
<tr>
<th>First Contact</th>
<th>Last Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/22/94</td>
<td>9/2/94</td>
</tr>
<tr>
<td>Month / Day / Year</td>
<td>Month / Day / Year</td>
</tr>
</tbody>
</table>

17. If applicable: anticipated date that identifiers will be removed from completed survey instruments and/or audio or visual tapes will be erased:

   ____________________________
   Month / Day / Year

18. Signature of Departmental Executive Officer

   ____________________________
   Date

   ____________________________
   Department or Administrative Unit

   Industrial Education & Technology

19. Decision of the University Human Subjects Review Committee:

   ☑️ Project Approved
   □ Project Not Approved
   □ No Action Required

   ____________________________
   Name of Committee Chairperson

   ____________________________
   Date

   ____________________________
   Signature of Committee
APPENDIX B: QUESTIONNAIRE
A. General
Please enter your personal information!

1. Name : .................................................................
2. Major : .................................................................
3. Gender : □ male □ female
4. Class Level : □ Freshmen □ Sophomore □ Junior
   □ Senior □ Graduate

B. Background in Computer Experience
Please check all that apply to you!

1. Have you ever taken any college-level course in computer literacy and/or
   computer programming? □ no □ yes, please explain ..................
2. Do you have any computer at home/dorm/apartment? □ no □ yes
3. Where do you usually use a computer?
   □ Computation Center □ Home
   □ Department/office □ other, please explain ..................
4. What kind of computer do you use?
   □ IBM compatible □ Mainframe/workstation
   □ Apple/Macintosh
5. How often do you use a computer?
   □ everyday □ once a week or less
   □ almost everyday □ never
   □ several days a week
6. The software packages you have used:
   □ Word processing □ Programming
   □ Spreadsheet □ Educational program (e.g. CAI lesson)
   □ Graphing and graphics □ other, please explain ..................
7. How would you describe your knowledge of the computer?
   □ Beginner □ Advanced
   □ Intermediate
8. How long have you been using computers?
   □ less than 1 year □ more than 3 years
   □ 1 to 3 years
C. CAI Lesson Evaluation

After completing the lesson, check your attitudes toward the statements below!
1. strongly disagree, 2. disagree, 3. neutral, 4. agree, 5. strongly agree

<table>
<thead>
<tr>
<th>Subject matter</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Objectives are stated clearly.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Topics are logically presented.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Subject matter is easy to understand.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Examples are clear and helpful.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Answers to the exercises and quizzes are helpful.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Question items are clearly stated.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Subject matter is accurate.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Presentation</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Program is free of technical problems.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Information on the screen is easy to read.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Program is free of spelling and grammatical errors.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Program is self instructed (you can run it without help).</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Color increases the instructional value of the program.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Graphics increase the instructional value of the program.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Feedback on the exercises and quizzes is helpful.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Student Interaction</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The student is actively involved in the program.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. The student controls the pace of the program.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. The student can access the menu to change topics.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. The student can go forward and backward through topics.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. The student can exit any time and from any page.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. The student can control the sequence of the topics.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Program interaction</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Feedback is immediate.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Feedback is non threatening.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Program gives the answers to the exercises and quizzes.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Program has the ability to suggest to branch/loop depending upon students' performance.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX C: PRETEST (POST-TEST)
**Pretest (Post-test):**

**Basic Electronics: DC Circuit**

**Direction:** Select the letter of the ONE choice which best completes the statement or answers the question. Please answer the questions to the best of your ability. Skip the question that you don't understand.

**Topic 1: Basic quantities**

1. What is NOT the definition of electrical current?
   a. The rate of flow of electrons.
   b. The net movement of free electrons from one point to another.
   c. The amount of charge moves past a given point in one second.
   d. The electrical charge that is carried by $6.25 \times 10^{18}$ electrons.

2. If 50 coulombs flow a point in a wire in 10 seconds, what is the current?
   a. 50 A  
   b. 5 A  
   c. 0.5 A  
   d. 0.2 A

3. Voltage is measured in:
   a. joules per second  
   b. volt  
   c. coulomb  
   d. answer a and b are correct

4. Twenty joules of energy are used to move 10 coulombs of charge from the negative terminal of a battery through a wire to the positive terminal, what is the battery voltage?
   a. 200 V  
   b. 20 V  
   c. 2 V  
   d. 0.5 V

5. Which one of the following is NOT a type of energy source?
   a. battery  
   b. solar cell  
   c. generator  
   d. potentiometer

6. Which statement is NOT true?
   a. Resistance is the opposition to current.
   b. One ohm is the resistance when there is one coulomb and one volt applied.
   c. Resistance is measured in the unit of ohms.
   d. An electrical component having the property of resistance is called a resistor.

7. A resistor has four bands, the first band is brown, second is red, third is brown, and fourth is gold, what is the resistor?
   a. 120 $\Omega \pm 5\%$  
   b. 120 $\Omega \pm 10\%$  
   c. 12 $\Omega \pm 5\%$  
   d. 12 $\Omega \pm 10\%$

8. A 56 $\Omega$ resistor with 10% tolerance is coded by colors of:
   a. blue, green, black, and silver  
   b. green, blue, black, and silver  
   c. green, blue, brown, and gold  
   d. blue, green, brown, and silver
9. The instrument used to measure current is:
   a. ammeter c. ohmmeter
   b. voltmeter d. potentiometer

10. To measure a voltage drop, voltmeter must be connected:
   a. series c. series-parallel
   b. parallel d. series or parallel

**Topic 2: Ohm's Law**

1. What is the Ohm's law formula for current?
   a. \( I = \frac{V}{R} \) c. \( I = \frac{R}{V} \)
   b. \( I = V \cdot R \) d. \( I = V \cdot \frac{1}{R} \)

2. If the voltage across a fixed value resistor is tripled, does the current increase or decrease, and by how much?
   a. decreases by six times c. increases by six times
   b. decreases by three times d. increases by three times

3. When \( V = 12 \text{ V} \) and \( R = 10 \Omega \), the current is:
   a. 1.2 A c. 12 mA
   b. 1.2 mA d. 1.2 \( \mu \text{A} \)

4. When \( V = 50 \text{ V} \) and \( R = 10 \text{ M\( \Omega \)} \), the current is
   a. 5 mA c. 5 \( \mu \text{A} \)
   b. 50 mA d. 50 \( \mu \text{A} \)

5. When \( I = 10 \text{ mA} \) and \( R = 27 \Omega \), the voltage is:
   a. 270 kV c. 27 V
   b. 270 mV d. 27 mV

6. When \( I = 2 \text{ A} \) and \( R = 10 \Omega \), the voltage is:
   a. 0.2 V c. 2 V
   b. 20 V d. 20 mA

7. When \( V = 10 \text{ V} \) and \( I = 5 \mu \text{A} \), the resistance is:
   a. 200 k\( \Omega \) c. 2 k\( \Omega \)
   b. 2 M\( \Omega \) d. 50 M\( \Omega \)

8. When \( V = 12 \text{ V} \) and \( I = 1 \text{ mA} \), the resistance is:
   a. 12 \( \Omega \) c. 120 k\( \Omega \)
   b. 12 M\( \Omega \) d. 12 k\( \Omega \)

9. If a resistor has 10 V across it and 2 mA flowing through it, the power is:
   a. 20 mW c. 5 mW
   b. 20 W d. 0.2 W

10. A 10-\( \Omega \) resistor is connected across the terminals of a 2-V battery. What is the power dissipation in the resistor?
    a. 4 W c. 0.2 W
    b. 0.4 W d. 50 W
**Topic 3: Series circuits**

1. A series circuit consists of a 4.7 kΩ, a 5.6 kΩ, and a 10 kΩ resistor. The resistor that has the most voltage across it is:
   a. the 4.7 kΩ  
   b. the 5.6 kΩ  
   c. the 10 kΩ  
   d. impossible to determine from given information

2. There are six resistors in a given series circuit and each resistor has 5 V dropped across it. The source voltage is:
   a. 5 V  
   b. dependent on the current  
   c. 30 V  
   d. dependent on the resistor values

3. The total resistance between terminals A and B is:
   a. 4 A  
   b. 4 mA  
   c. 7.2 kΩ  
   d. 10 mA  
   e. 6.3 kΩ  
   f. 1.062 kΩ  
   g. 500 Ohm  
   h. 1100 Ω

4. When a 10 V battery is applied between terminals A and B, the current is:
   a. 0.5 kΩ  
   b. 5 mA  
   c. 1.5 kΩ  
   d. 10 mA

5. The voltage drop across R2 is:
   a. 3 V  
   b. 2 V  
   c. 4 V  
   d. 4.5 V
6. The voltage drop across R1 is:

\[ V_{R1} = ? \]

\[ V_S = 1 \text{ V} \]

\[ I = 1 \text{ mA} \]

R2 = 100 Ohm

- a. 0.9 V
- b. 0.5 V
- c. 0.1 V
- d. impossible to calculate

7. The voltage drop across terminals A and B is:

\[ V_{A-B} = ? \]

\[ R_1 = 100 \text{ Ohm} \]

\[ R_2 = 200 \text{ Ohm} \]

\[ V = 10 \text{ V} \]

\[ I = 1 \text{ mA} \]

- a. 7 V
- b. 0.7 V
- c. 3 V
- d. 9.7 V

8. What is the total voltage between terminals A and B?

\[ A \rightarrow 3 \text{ V} \rightarrow 9 \text{ V} \rightarrow 9 \text{ V} \rightarrow 3 \text{ V} \rightarrow B \]

\[ V_A \rightarrow V_9 \rightarrow V_9 \rightarrow V_3 \rightarrow V_B \]

- a. 0 V
- b. 24 V
- c. 6 V
- d. 12 V

9. The voltage drop across R1 is:

\[ V_{R1} = ? \]

\[ V_S = 6 \text{ V} \]

R2 = 20 Ohm

- a. 3 V
- b. 2 V
- c. 4 V
- d. 4.5 V

10. The voltage drop across terminals A and B is:

\[ A \rightarrow 12 \text{ V} \rightarrow 270 \text{ Ohm} \rightarrow 150 \text{ Ohm} \rightarrow 150 \text{ Ohm} \rightarrow B \]

\[ 200 \text{ Ohm} \]

\[ 150 \text{ Ohm} \]

\[ 150 \text{ Ohm} \]

\[ 330 \text{ Ohm} \]

\[ 150 \text{ Ohm} \]

\[ 150 \text{ Ohm} \]

- a. 7 V
- b. 8 V
- c. 9 V
- d. 3 V
**Topic 4: Parallel Circuit**

1. In a parallel circuit, each resistor has  
   a. the same current  
   b. the same voltage  
   c. the same power  
   d. a, b, and c

2. The following resistors are in parallel across a voltage source: 390-Ω, 560-Ω, and 820-Ω. The resistor with the LEAST current is  
   a. 390 Ω  
   b. 560 Ω  
   c. 820 Ω  
   d. impossible to determine from given information

3. When a 1.2 kΩ resistor and a 100 Ohm resistor are connected in parallel, the total resistance is:  
   a. between 50 Ω and 100 Ω.  
   b. between 100 Ω and 1.2 kΩ.  
   c. more than 1.2 kΩ.  
   d. less than 50 Ω.

4. The total resistance between terminals A and B is:  
   ![Parallel Circuit Diagram]
   a. 4 kΩ  
   b. 2 kΩ  
   c. 250 Ω  
   d. 100 Ω

5. The current flows through R1 is:  
   ![Current Flow Diagram]
   a. 20 mA  
   b. 5 mA  
   c. 80 mA  
   d. 4 mA

6. The current flows through R1 is:  
   ![Current Flow Diagram]
   a. 9 mA  
   b. 6 mA  
   c. 4.5 mA  
   d. 3 mA
7. The voltage drop across R4 is:

\[ \text{It} = 20 \text{mA} \]

\[ V_{R4} = ? \]

a. 4 V c. 10 V
b. 5 V d. 20 V

8. Five 60-W bulbs are connected in parallel. What is the total power?

a. 15 W c. 300 W
b. 60 W d. 12 W

9. Two 500-Ω resistors are in parallel. The total resistance is

a. 1000 Ω c. 500 Ω
b. 750 Ω d. 250 Ω

10. If there are a total of 100 mA into a parallel circuit consisting of three branches and two of the branch currents are 40 mA and 20 mA, the third branch current is

a. 20 mA c. 60 mA
b. 40 mA d. 160 mA

---

**Topic 5: Series-Parallel Circuits**

1. Which of the following statements are true concerning the figure below:

\[ A \quad R1 \quad R2 \quad R3 \quad R4 \quad R5 \quad B \]

a. R1 and R2 are in series with R3, R4, and R5.
b. R1 and R2 are in series.
c. R3, R4, and R5 are in parallel.
d. The series combination of R1 and R2 is in parallel with the series combination of R3, R4, and R5.
e. b and d

2. In the figure of question 1, when all resistors are 10 Ω the total resistance is:

a. 2.5 Ω c. 12.5 Ω
b. 7.5 Ω d. 50 Ω
3. If all of the resistors have the value, when voltage is applied across terminals A and B, the current is?

- a. greatest in R5
- b. greatest in R1 and R2
- c. greatest in R3, R4, and R5
- d. the same in all the resistors

4. Concerning the figure below, which one of the following statements is true?

- a. Vs1 will affect I2 only
- b. Vs1 will affect I1 only
- c. Vs2 will affect I2 only
- d. Vs2 will affect I1 only

5. The current through A 5 kΩ resistor is:

- a. the same as I2
- b. I2 + I3
- c. I1-I2-I3
- d. I1-I2+I3

6. When 12.5 V is applied across terminals A and B, the current I1 is:

- a. 0.125 mA
- b. 0.25 mA
- c. 0.5 mA
- d. 1 mA

7. When a load resistance is connected to the output of a voltage divider circuit, the current drawn from the source:

- a. decreases
- b. increases
- c. remains the same
- d. becomes zero
8. The output of a certain voltage divider is 9 V with no load. When a load is connected, the output voltage
   a. increases  c. decreases
   b. remains the same  d. becomes zero
9. A Thevenin equivalent circuit consists of
   a. a voltage source in series with a resistance
   b. a voltage source in parallel with a resistance
   c. a current source in parallel with a resistance
   d. two voltage sources and a resistance
10. On which one of the following voltage range settings will a voltmeter present the minimum load on a circuit?
    a. 1 V  c. 100 V
    b. 10 V  d. 1000 V
APPENDIX D: OBSERVATIONAL QUESTIONS
## OBSERVATIONAL QUESTIONS

A checklist completed by the investigator while observing each subject via videotape.

<table>
<thead>
<tr>
<th>Question</th>
<th>□ no</th>
<th>□ yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Did he/she open the Help menu?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Did he/she open &quot;Introduction&quot;?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Did he/she open &quot;Basic Quantities&quot;?(how long?)</td>
<td>□ no</td>
<td>□ yes, (............mt)</td>
</tr>
<tr>
<td>4. Did he/she do the exercises and/or quizzes?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Did he/she open &quot;Ohm's Law&quot;?(how long?)</td>
<td>□ no</td>
<td>□ yes, (............mt)</td>
</tr>
<tr>
<td>6. Did he/she do the exercises and/or quizzes?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Did he/she open &quot;Series Circuits&quot;?(how long?)</td>
<td>□ no</td>
<td>□ yes, (............mt)</td>
</tr>
<tr>
<td>8. Did he/she do the exercises and/or quizzes?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Did he/she open &quot;Parallel Circuits&quot;?(how long?)</td>
<td>□ no</td>
<td>□ yes, (............mt)</td>
</tr>
<tr>
<td>10. Did he/she do the exercises and/or quizzes?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Did he/she open &quot;Series-Parallel Circuits&quot;?</td>
<td>□ no</td>
<td>□ yes, (............mt)</td>
</tr>
<tr>
<td>12. Did he/she do the exercises and/or quizzes?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Did he/she open &quot;Cross References&quot;?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. How long did it take to complete the lesson?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Did he/she use a calculator?</td>
<td>□ no</td>
<td>□ yes</td>
</tr>
<tr>
<td>16. Did he/she use a scratch paper and pencil?</td>
<td>□ no</td>
<td>□ yes</td>
</tr>
</tbody>
</table>
APPENDIX E: INFORMED CONSENT FOR PARTICIPATION
SIGNED INFORMED CONSENT for Participation in Research Involving Human Subjects
Iowa State University

Title of Project: The development of computer-assisted instruction (CAI) using ABC for teaching basic electronics

Purpose: Thesis research for MS degree in Industrial Education and Technology, ISU

Principal Investigator: Herman D. Surjono, graduate student

(1) Purpose:
The purpose of this study is to develop a CAI lesson using ABC for teaching basic electronics and to examine its performance by exploring the students' perceptions after completing the lesson.

Procedures:
The subjects will:
- need to have a Project Vincent account.
- answer a pretest.
- access the Electronics lesson and complete the package program.
- respond to questionnaires and a post-test.
The investigator will:
- administer a pretest.
- observe the subjects learning the lesson, take notes.
- videotape the subjects learning the lesson.
- administer a post-test.

(2) Any reasonably foreseeable discomforts or risks: None

(3) Questions or inquiries:
The investigator will answer any questions regarding this study. The investigator can be reached by calling (515)296-7943 or

(4) Confidentiality:
The subjects will not be referred to by name or any other overt form of recognition in reporting of results of this study. The videotape of the procedure will be erased soon after analyzing data and will not be shown to anyone without consent of the subjects.

(5) Location: E116 Lagomarcino.

(6) Time: Weekdays evening at 7.00 - 9.00 pm for three days.

(7) The subjects are free to withdraw their consent and to discontinue participation from the project without prejudice to the subjects.

Signature below indicates that the subjects understand and agree to these conditions

Participant's Name and Signature
APPENDIX F: HOW TO ACCESS THE CAI LESSON
HOW TO ACCESS THE CAI LESSON:
The Electronics lesson can be accessed via a workstation. Public workstations are available in 139 Durham, 248 Durham, and E116 Lagomarcino. Using one of these workstations, you may register for a Project Vincent account.

Registering for a Project Vincent account
When you see one of the workstations, there will be a login window on the screen (if the screen is blank, move the mouse). Begin by using the workstation's mouse to position the pointer over the REGISTER box and press the left mouse button. You will be prompted to enter your first name, family (last) name, birth date, and ISU identification number. Your information must match the records from the Registrar's Office.

After your information is accepted, you will be asked to choose and enter a username by which your account will be identified. This name cannot be changed and it will last for the life of the account. Your username can be up to eight lowercase letters and numbers in any combination you choose.

Finally, choose a password of up to sixteen characters (letters, numbers, and symbols). You will have to enter the same password twice for verification. As you type your password, it will not appear on the screen.

After completing this process (which should take about five minutes) you will be alerted that your registration has accepted for processing. Please allow 24 hours for processing. You can attempt to login to Project Vincent and if your account processing is complete, you will have access, otherwise you can wait and try later.

Accessing the Electronics Lesson
To access the Electronics lesson, enter the following commands after the "vincent%" prompt:

First-time Users:
vincent% add abc <RETURN>
vincent% abcinit <RETURN>
vincent% lesson electronics <RETURN>

After a brief pause, Vincent will display a title page.

Subsequent Sessions:
vincent% add abc <RETURN>
vincent% lesson electronics <RETURN>

To begin the lesson, click on "start" button in the lower right corner of the title page.

To learn about lesson operation, click on "?" button at the top of the lesson window.

To exit the lesson, click on "EXIT" button at the top of the lesson window.