LEARNING FROM SPEECH PROMPTS IN A COMPUTER-BASED TUTORIAL ON ELECTRIC CIRCUITS

by

© Kayode Mathews Arowolo

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Abstract

Despite the acknowledged roles speech may play in multimedia instructional packages, there is yet no consensus on how to integrate speech in multimedia learning resources. Researchers in multimedia learning advocate for clearer directions on the role of audio in multimedia instruction.

This dissertation was concerned with two design guidelines for incorporating speech in multimedia instruction. Mann's temporal speech cueing (that is, a multimedia learning environment with graphics and a brief spoken instruction, direction, or hint) and Mayer's off-loading textual information into narration to "balance the input" (that is, a multimedia learning environment with graphics and a balance of spoken and on-screen information). Three versions of an Electric Circuits' Tutorial (ECT) were developed ─ convergent temporal speech cueing version based on Mann's structured sound function model, and the narrated screen text and on-screen text versions based on Mayer's off-loading textual information into narration. The aim was to compare the learning processes in the three versions in order to determine which version would help below-average high school Physics students in Nigeria to focus their attention on critical information in the tutorial.

The following research questions guided the study: How do Ilorin Senior Secondary School (SSS) (grade 11) students in the convergent temporal speech cueing group, narrated screen text group, and on-screen text group differ in their attentional focus on the electric circuits tutorial?, how do Ilorin SSS students (grade 11) in the three groups differ in their performance following the intervention with the Electric Circuits Tutorial?, and how do Ilorin SSS students (grade 11) in the three groups differ in their learning of electric circuits after a latency period of six weeks?

Analyses of the self-explanations of the three experimental groups revealed that the three groups were significantly different from each other in the quality of participants' self-explanations. However, the analyses of the posttest and delayed posttest data show that between groups modality effect was non-significant. Therefore, in order to integrate digitized speech in multimedia instruction for below-average students in Nigeria, instructional designers need to question existing design guidelines. Both the temporal speech cues and narrated text have their roles in instructional multimedia.

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1. INTRODUCTION

Over the past several years, digitized speech has been applied to multimedia visuals in different ways, two of which are narration and cueing. Narration features a multimedia learning environment with graphics and a balance of spoken and on-screen information while cueing features a multimedia learning environment with graphics and a brief spoken instruction, direction, hint, partial answer, reminder, or caution. Which of these two ways helps below-average high school Physics students in Ilorin, Nigeria to focus their attention on critical and important information in the multimedia? This research focused on psychological dimensions to sound in multimedia, though it is recognized that there is significant aesthetic scholarship on the significance of sound in multimedia, including music and narration, which is beyond the purview of this research.

The problem addressed in this dissertation is that there is no consensus on how to integrate sound in multimedia instruction because adding sound to multimedia instruction means different things to different people (Mann, 2009). Therefore, chapter one of this doctoral dissertation is an introduction to the background and the context of the problem. Furthermore, this chapter is a description of the problem, three research questions, and the significance of the research.

1.1 Background of the Problem

Learning from educational multimedia requires listening to the materials and reading the text. When adults listen to educational multimedia they acquire gist (broad, less-detailed trace of the materials) from the auditory sensations and verbatim information (detailed trace of the materials) from reading the text (Mann, Schulz, Cui & Adams, 2012). Mayer (1997) noted that "meaningful learning occurs by selecting information from the verbal and visual store; organizing the information into a coherent mental representation; and making referential connections between the verbal and visual representations" (p. 4). However, it is possible to combine elements from the audio/verbal store and visual store inappropriately when attention is distracted or overloaded (Mann et al., 2012). Therefore, there is a need for purposeful advice, grounded in research, on how to integrate speech in multimedia instruction.

Furthermore, research findings suggest that "school-aged students using educational multimedia are unable to generate sufficient gist to solve problems because of their under-developed phonological loop…" (Mann et al., p. 166). The phonological loop, which is responsible for acoustic and verbal information, is one of the components in Baddeley's model of the working memory. The under-developed phonological loop "…….limits school-aged students' mental ability to generate sufficient referential connections between the speech prompts and the limited text, and the speech prompts and diagrams" (Mann et al., 2012, p. 166). Therefore, researchers in multimedia learning advocate for clearer directions on the role of audio in multimedia instruction. That is, should audio replace or enhance on-screen instructions and feedback? (Koroghlanian & Klein, 2004).

Sound is critical to maintaining attention. Research has shown that attention is critical to learning (Fougnie, 2008; Schweizer, Moosbrugger & Goldhammer, 2005); without attention there can be no learning. Sound helps to gain attention, helps to focus and hold our attention, helps to activate existing images and schemas, engages a learner's interest over time and provides a reading context (Bishop, 2012; Mann, 2012). According to Bishop (2012), there are “few guidelines available for those instructional designers who are interested in finding theoretical and/or conceptual direction for incorporating sound most effectively” (p. 5). Some instructional designers add sound to their learning packages as an afterthought (Bishop, 2012).

Mann (2009) identified at least eight design guidelines of computer-assisted instruction ─ structured sound function, whatever works, design-by-type, favorite feature, favorite method, balance the input, maximum impact, and cognitive load first. However, this dissertation is concerned with two of these guidelines: temporal speech cueing (from the Structural Sound Functions model) (Mann, 2008) and Mayer’s (2002) off-loading textual information into narration to “balance the input” (Mann, 2008). This dissertation is concerned with these two design guidelines because they have previously been used in research-based studies and therefore, are peer-reviewed.

This dissertation research involved the design and a formative evaluation of three versions of a computer-based tutorial ─ convergent temporal speech cueing, narrated screen text, and on-screen text ─ that aimed to compare the learning processes by senior secondary school students in Ilorin, Nigeria. In this dissertation, self-explanation (Chi, Lewis, Reimann & Glaser, 1989; Chi & VanLehn, 1991) protocols were collected to investigate participants' learning processes during the pilot test and validation of the three versions of the ECT.

1.2 Context of the Problem

As mentioned earlier, two of the theories of multimedia learning in current use are the Cognitive Theory of Multimedia Learning (Mayer, 1997) and the Attentional Control Theory of Multimedia Learning (ACTML) (Mann, 2006). The more widely cited theory of audio-visual learning is Mayer's (1997) cognitive theory of multimedia learning, which includes a "split attention principle" and a "modality principle". According to Mayer and Moreno (2000), the split attention principle states that learning is better when attention is not divided between mutually referring information. The modality principle proposes that "animation plus narrated screen text" spoken by a person, produces better retention and transfer in students than "animation plus on-screen text". Mann (2008) explained that "researchers who aim to balance verbal and nonverbal representations in students' working memory by weeding and off-loading information from the visual events into sound signals (Mayer, 2001, 2003) may be said to define multimedia learning as a balanced input of pictures and words (spoken or written)" (p. 1160). These principles rely on Paivio's (1986) dual coding theory, which assumes that there are two cognitive systems called imagens, and logogens, where the imagens are the "non-verbal system of spatial codes and the logogens are the language-like system of verbal codes" (Mann, 2008, p. 1160). The learner is assumed to be able to make connections between information presented in verbal and non-verbal forms by integrating them into a coherent and meaningful form (Mayer, 1997).

While Mayer's cognitive theory of multimedia learning has been widely cited, Segers, Verhoeven and Hulstijn-Hendrikse (2008) state that it "cannot be directly transferred to the school situation, for a number of reasons" (p.378). There are several delimitations in Mayer's research on multimedia learning - firstly, applying Mayer's descriptive theory of learning, as a prescriptive model for designing instruction is problematic because instructional design is concerned with optimizing the process of instruction rather than the process of learning (Reigeluth & Stein, 1983). Secondly, the participants in Mayer's (2001) research were American undergraduate psychology students (supposedly students with high cognitive ability), not high school students in Ilorin, Nigeria as in the case of this research. Thirdly, Mayer's (2001) experiments used non-curricular topics of scientific explanations on physical and mechanical systems and narrated the screen texts. Fourth, the research design in Mayer's experiments was without a delayed post-test to check for forgetting. Only impact testing of the effect of multimedia was conducted, which Mayer categorized as "learning". Furthermore, some researchers have noted that Mayer's principles are simplistic and do not take other ingredients such as motivation into consideration when talking about students' learning from multimedia (Astleitner & Wiesner, 2004).

The Attentional Control Theory of Multimedia Learning (ACTML) (Mann, 2006, 2008, 2009) is a theory of learning from multimedia. According to Mann (2008), the ACTML is based on two psychological theories ─ Baddeley's (1986) working memory where verbal memory is either spoken or written; and Brainerd and Reyna's (1995) fuzzy trace theory. The fuzzy-trace theory is a cognitive theory which recognises that memory has dual traces ─ verbatim traces which are detailed memories, and gist traces which may be regarded as broad, less-detailed memories (Brainerd and Reyna, 1995). The Structured Sound Functions (SSF) model (Mann, 1992) is the corresponding instructional design model that has been well-received (Fassbender, Richards, Bilgin, Thompson & Heiden, 2012). Taken together the psychological descriptions of focusing attention to learn in the ACTML, and the prescriptions for structuring functions for sound provided in the SSF model of instructional design can be properly described as a two-way street (Mayer, 2003). When integrated purposefully into a multimedia instruction, "sound might supplement instruction by providing the additional content, context, and construct support necessary to overcome many of the acquisition, processing, and retrieval problems one might encounter while learning" (Bishop & Sonnenschein, 2012, p. 12).

Applying Mann's (2008) approach to the design of multimedia instructional applications, the teacher's commentary can be recreated by using text to accompany the pictures, or a voice can be used to give warnings or reinforce the text (Periago, Pejuan, Jaén & Bohigas, 2009) in order to focus students' attention. Fassbender et al. (2012) said that, "Mann (2008) makes a connection between sound, memory, and the design of multimedia (teaching) material that provides a compelling case for the use of sound to focus attention" (p. 492). The authors observed that while purely visual information and instructions are often ignored, missed or forgotten, "multimedia sound is both durable and resistant to interference and forgetting" (Mann, 2008, cited in Fassbender et al., 2012, p.492).

Nevertheless, Mann's SSF model may be misapplied by using simultaneous narration with text, as in most of Mayer's studies. Wang found no statistically significant results with narration. "Narration" is a stochastic sound design and may not help to focus a student's attention on the computer interface (Mann, 1996). Whereas, White (2012) found statistically significant results in the reduction of idle-time through changing the modality of instruction from stochastic visual cues to auditory cues delivered via the SSF model of instructional design, Adams, Mann and Schulz (2006) found no statistically significant differences with 7^{th} graders learning fractions.

1.3 Statement of the Problem

Although, the uses and functions of sound in multimedia have gained widespread attention among instructional designers, multimedia researchers, and educational psychologists, there is no consensus on how multimedia learning materials should be designed for senior secondary school students. Learning from multimedia instruction is difficult if the materials are not well-designed (Roy & Chi, 2005). Therefore in this research, a convergent temporal speech cueing version, a narrated screen text version, and an on-screen text version of an Electric Circuits Tutorial for below-average senior secondary school Physics students in Ilorin were designed to determine which version would focus their attention on critical information in the tutorial.

1.4 Research Questions

This research consists of three experimental treatments. Treatment one (T1) (called the on-screen text version) features graphics and written statements about a phenomenon. Treatment two (T2) (called the narration treatment) includes a visual and written text component, coupled with direct narration. That is, a female voice read out the screen text. Treatment three (T3) (called the temporal speech cues version) features graphics and a brief spoken instruction, direction, hint, partial answer, or reminder. Based on these treatment conditions, three research questions were derived:

1) How do Ilorin Senior Secondary School (SSS) (grade 11) students in the convergent temporal speech cueing group, narrated screen text group, and on-screen text group differ in their attentional focus on the electric circuits tutorial?

"Electric circuits" is operationalized as outcome statements contained in the curriculum in Ilorin (Ministry of Education, 2007). "Attentional focus" is operationalized as generating a greater number of quality self-explanations according to the criteria specified in Chi *et al.* (1989, 1991) - strategic, plan-like or goal oriented statements; expanding or refining preconditions; explicating consequences of actions; and giving meaning to quantitative expressions. To mitigate the effect of verbosity, "scientific explanation" is further operationalized as more details and more gist of the unit on “electric circuits”. “Convergent temporal speech cueing” is operationalized as a pre-recorded instruction, navigational direction, hint, feedback, or a reminder, spoken by a natural young female voice (Mann, 1992). “Narrated screen text” is operationalized as spoken words by a person about a phenomenon (Mayer, 1997). “On-screen text” is operationalized as written statements about a phenomenon or images (Mayer, 1997).

2) How do Ilorin SSS students (grade 11) in the three groups differ in their performance following the intervention with the Electric Circuits Tutorial?

“Performance on electric circuits” is operationalized as the number of correct answers on an immediate post-test (based on items from Determining and Interpreting Resistive Electric Circuits Concepts Test (DIRECT) (Engelhardt & Beichner, 2004) in Appendix H.

3) How do Ilorin SSS students (grade 11) in the three groups differ in their learning of electric circuits after a latency period of six weeks? “Learning of electric circuits” is operationalized as a permanent change in performance measured by the number of correct answers on a delayed post-test, six weeks after the intervention (based on items from Determining and Interpreting Resistive Electric Circuits Concepts Test (DIRECT) (Engelhardt & Beichner, 2004) in Appendix H.

From the first research question, the following hypotheses were formulated:

The null hypothesis H_o is "modality and attentional focus are independent".

The alternative hypothesis H_a is "modality and attentional focus are not independent".

1.5 Significance of the Research

Several aspects of this research have both theoretical and practical significance. The significance is highlighted below:

1.5.1 Knowledge about designing multimedia instruction

The significance of this research is that it might add to the understanding of integrating sound to multimedia instructional presentations, for a given population. That is, current knowledge of designing multimedia instruction for senior secondary school (SSS) students in Nigeria could be improved and refined. Furthermore, knowledge about how below-average high school science students in Nigeria learn from a self-paced multimedia tutorial that was designed for them could be improved. Learning from multimedia is difficult because it requires learners to actively comprehend and integrate information across diverse sources and modalities (Roy & Chi, 2005). Some students experience problems in trying to learn difficult or unfamiliar content from the on-screen text.

Although multimedia is pleasing to most SSS students, their enjoyment is usually either uncorrelated or negatively correlated with learning (Clark & Feldon, 2005) because unlike entertainment multimedia, educational multimedia requires active listening and reading instructions and feedback presented by the program or website (Mann, 2008). Reading instructions and feedback requires mental articulation of that instruction, feedback, hint, or a program direction by expressing it inwardly or sounding it out. Meaningful learning from multimedia requires learners to construct coherent integrated representations (Roy & Chi, 2005; Mayer, 2001). Mann, Schulz and Cui (2012) observed that when a student reads a text within a multimedia environment, he/she must be able to “mentally articulate their own version of the meaning in the text” (p. 34).

1.5.2 Forgetting in multimedia learning

A related educational significance of this research concerned how much or how little was forgotten or remembered after a six-week latency period following the participants use the Electric Circuits’ Tutorial. This enabled the researcher to assess the participants’ learning of electric circuits after the latency period to determine the durability or resilience of the different modalities.

1.5.3 Competing theory

A third significant benefit of research on attentional control is the comparison of convergent temporal speech-cueing as described in the Structured Sound Function (SSF) model of instructional design (Mann, 2008) with Mayer’s (1997) cognitive theory of multimedia learning. This process helped to determine which of the theories focused the students’ attention better when learning from multimedia. This knowledge may be helpful when designing multimedia instruction for below-average SSS physics students in Ilorin, Nigeria.

1.5.4 Local access to a computer-based tutorial

A significant positive educational side-effect of this research is the introduction of an improved computer-based Electric Circuits' Tutorial into Nigerian secondary schools. Heretofore computer-based instructional packages on science and other subjects designed for the Nigerian curriculum had not been available in Nigeria. Gambari and Yusuf (2014) examined problems in Physics education within the secondary school in Nigeria, and called for "a well-developed and adequately validated CAI package of this nature to support student's learning in Physics" (p.126).

1.6 Summary

Chapter one was an overview of the background and context of the problem addressed by this doctoral research. The problem addressed by the research was that there is no consensus on how multimedia learning materials should be designed for below-average senior secondary school students in Nigeria because research on the modality principle and the SSF model has had mixed results. Researchers and practitioners have not arrived at a consensus whether sound should be integrated in multimedia learning materials as narration or as speech cues to help focus learners' attention. In order to determine how multimedia materials should be designed for below-average senior secondary school students in Nigeria, the research involved the design, quality review, and validation of three versions of a tutorial referred to as Electric Circuits' Tutorial. The chapter concluded with the three research questions, which sought to investigate how learners' attention is focused while using the three versions of the ECT. The next chapter is a review of the extant literature in multimedia instructional materials and computers in science instruction. Moreover, chapter two is a description of the theories of multimedia learning that guided the design of the Electric Circuits' Tutorial (ECT).

2. REVIEW OF THE LITERATURE

Chapter two of this doctoral dissertation is a review of the extant literature on multimedia and computers in science instruction, particularly in Physics. In this chapter, a review of the literature on Mayer's cognitive theory of multimedia learning and Mann's attentional control theory of multimedia learning is also presented. These theories formed the frameworks for the design of the three versions of the electric circuits' tutorial (ECT). The ECT included simulations, graphics, sound (narration or speech cues) and written texts; therefore, this chapter is furthermore a review of the literature on simulations, sound in multimedia and the modality principle. Additionally, Chapter two is a review of the extant literature on formative evaluation in order to understand its purpose in instructional design and how it was applied to the ECT. This chapter is also a review of the literature on self-explanation and how it has been used in multimedia learning environments. The definition of terms can be found in Appendix A.

2.1 Literature in multimedia and computers in science instruction

A review of related literature, as indicated in the table below, shows that computer-assisted instruction (CAI) have been used in teaching science, particularly content-specific areas, with some mixed results. Some studies conducted in the area of multimedia in Physics teaching showed significant differences in students' performance between pre-test and post-test, while other studies showed no significant differences. However, there were other studies where the use of multimedia and performance were negatively correlated, that is, the use of multimedia led to a declined performance. The table below shows a review of the literature in multimedia and computers in science instruction, using the delivery (D), environment (E), content (C), and learner (L) format (Mann, 2005).

Table 1.

Literature in multimedia and computers in science instruction

Authors (Year)	Delivery	Environment	Content	Learner	Outcome
Mann *et al.* (2002)	Speech cues in a Computer Assisted Learning (CAL)	Classroom (n=30)	Science (Combustion)	Gr.4,5	p = .000, η2=0.147
Mann, Schulz, Cui, & Adams (2012)	Experiments with talking pedagogical agents	Computer labs (For experiment 1, n = 133; for experiment 2, n = 91)	English language (Usage of apostrophe)	Experiment 1: 4th and 5th grade students (aged 9-12 years). Experiment 2: 7th grade students (12-15 years old)	Statistically significant differences in learning gain between the participants in the speech cues group and those in the on-screen text cues. Agent movement and gesturing did not significantly affect student learning. No statistically significant difference

					between the groups in 7th grade.
Mayer & Moreno (1998)	Off-loading information to audio channel (balancing the input)	Lab	Science (Generators)	Undergrads	ES=1.17
Rotbain, Marbach-Ad & Stavy (2008)	Computer Assisted Instruction (CAI) with activity booklet	Classroom (n=61 from 5 classes for the experimental group and n=116 from 8 classes for the control group)	Molecular biology (genetics)	17 & 18 year olds in high school	$p < 0.001$, mean = 73, control group mean score = 61
Sorensen, Twidle, Childs & Godwin (2007)	Using Internet to teach science (Physics, chemistry & biology)	Higher education institutions and secondary	General use of the Internet to enhance science teaching in high schools	Science student teachers in PGCE (a 1-year teacher education course	Improved attitude & confidence in using the internet $p < 0.01$

		schools		for science graduates)	
Thornton & Sokoloff (1998)	Microcomputer-based laboratory (MBL)	Laboratories	Physics (force and motion)	Introductory Physics course for undergrads	Majority of students in MBL lab curricula answered questions in Newtonian manner
Huddle, White & Rogers (2000)	Analogies with computer simulations	Game-like environment n = 45, n = 102, n = 240	Science (chemical equilibrium)	Three groups: made up of grade 12 students; college students; and health science undergrads	College students had poor pre & post-test scores; improvement for school pupils was similar to that of health science undergrads
Trey & Khan (2008)	Computer-based analogies of observable phenomena	Classroom n = 15	Chemistry (Le Chatelier's principle)	12^{th} grade chemistry students	t(13) = 2.61 p = 0.017 mean score for experimental group (group A) = 90%

					mean score for control group (group B) = 68%
Adegoke (2011)	Modality effect of multimedia learning	Classroom n = 198	Linear momentum (impulse and momentum, Newton's laws of motion, and principle of conservation of linear momentum)	Senior Secondary School (SSS 2) Physics students	For recall items, $p < 0 .01$, partial $\eta^2 = .074$ Suggesting that learning outcomes of students in physics can be enhanced with multimedia instruction.
Gambari & Yusuf (2014)	Development and validation of a computer-based instructional package on Physics	n = 18 for individualized group validation; and n = 21 for cooperative group validation	Equilibrium of forces and simple harmonic motion	Senior Secondary School (SSS 2) Physics students	The authors stated that the development and validation of the CAI package was found "to produce a very good performance when used for physics instruction" (p. 1).

Elen & Van Gorp (2008)	Boundaries of the modality effect in multimedia learning	10 participants for each of the 24 experimental conditions; n = 240	Characteristics of different categories of animals.	Ten-year old pupils	Analysis of variance revealed no main effects of conditions for learning gains with respect to retention or transfer.
de Koning, Tabbers, Rikers, & Paas (2007)	Attention cueing as a means to enhance learning from an animation	40 undergraduate psychology students (10 males and 30 females)	cardiovascular system	Psychology undergraduates	Cueing enhanced comprehension and transfer performance for cued and uncued information.

2.2 Theories of multimedia instruction

Over the past several years, instructional design has evolved with many authors and scholars advancing some theories to guide instructional design. One of such theories applied to instructional design, is the Attentional Control Theory of Multimedia Learning (Mann, 2008). In this research, the Attentional Control Theory of Multimedia Learning (ACTML) and the Cognitive Theory of Multimedia Learning (CTML) were the frameworks for the design of the three versions of the Electric Circuits Tutorial (ECT) because this dissertation research examined how student's attention may be focused on critical information during learning from multimedia.

The ACTML forms the theoretical foundation for the Structural Sound Functions (SSF). This theory was chosen for the design of the temporal speech cues version of the tutorial in this research because it describes the structure of students' working attention while learning from multimedia. Also, the theory describes the manner in which students process information using different modalities in different ways (Mann, 2008). The following is a discussion of the ACTML and the CTML as they apply to this research.

2.2.1 Attentional Control Theory of Multimedia Learning

In this research, the central instructional design framework adopted for the speech cueing version was Mann's (2005) Attentional Control Theory of Multimedia Learning (ACTML). Information was presented to the learner using a combination of graphics and sound to control their attention on relevant materials of the ECT. The ACTML describes the relationship of the external stimuli perceived through the human senses (visual and auditory system) and the long-term memory. The figure below illustrates the cognitive structure of learning from multimedia according to Mann's (2005) ACTML.

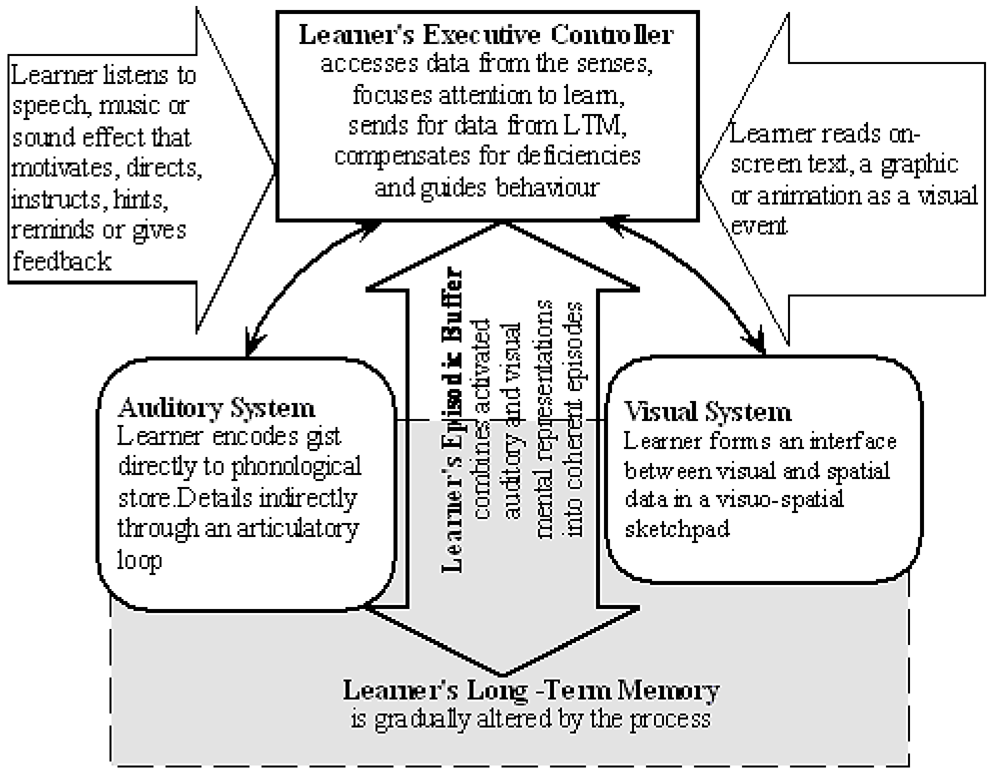

Figure 1. The structure and process of learning from multimedia according to the ACTML (Mann, 2008).

In his description of the structure and process of learning from multimedia, Mann (2008) noted that learning from multimedia begins when information is received through the senses (verbal and visual information received through the auditory and visual senses respectively). The executive controller then collects the information and establishes a two-way communication with the LTM. The learner sieves the gist from the auditory memory system and the images from the visual memory system and integrates them into a coherent form in the episodic buffer. The gist from the auditory memory is encoded directly into the phonological store while the details go “indirectly through an articulatory loop”. Also, by using the visual information, the learner creates an “interface between the spatial and visual information in the visuo-spatial memory” (p. 1162). This whole process leads to schema acquisition and alteration of the LTM. In the ECT, the learners captured information presented in graphics, animation and/or on-screen text through their visual senses while information presented as sound/speech cues was captured through their verbal senses. The executive controller worked to link the information with the long-term memory by focusing the learners’ attention while also communicating with the visual and auditory systems.

2.2.2 The Cognitive Theory of Multimedia Learning

The instructional design framework for the design of the on-screen text version and the narrated-screen text version of the ECT was the cognitive theory of multimedia learning (CTML) Mayer (1997). According to Mayer (1997), the CTML was derived from three theories: dual coding theory (Alan Paivio), cognitive load theory (John Sweller) and constructivist learning theory (Jean Piaget, Jerome Bruner). According to Moreno & Mayer (2000), the following are the assumptions underlying the cognitive theory of multimedia learning:

- Working memory includes independent auditory and visual working memories (Baddeley, 1986)

- Each working memory has a limited capacity (Sweller, 1988)
- Humans have separate systems for representing verbal and non-verbal information (Paivio, 1986)
- Meaningful learning occurs when a learner selects relevant information in each store, organizes the information into a coherent representation, and makes connections between corresponding representations in each store (Mayer, 1997).

According to the theory, Mayer (1997),

> active learning occurs when a learner engages three cognitive processes – (1) selecting relevant words for verbal processing and selecting relevant images for visual processing, (2) organizing words into a coherent verbal model and organizing images into a coherent visual model, and (3) integrating corresponding components of the verbal and visual models (p. 11).

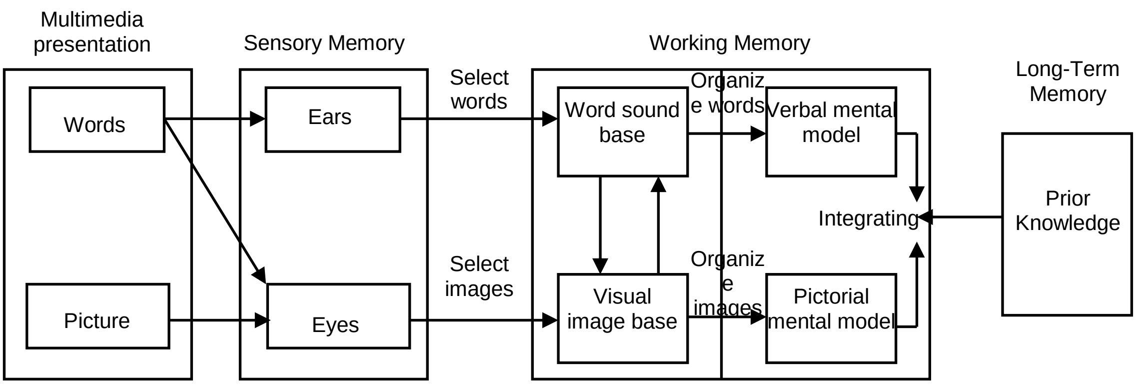

Figure 2. Cognitive theory of multimedia learning (Mayer, 1998)

Meaning making from the gist of multimedia instruction involves the process of the learner sifting through the information presented and selecting the relevant ideas that would later be used in knowledge construction (Mayer, 1997). The process of selection of verbal and visual material is then followed by organizing into a logical and consistent way for further meaning making where the information is used to create a mental model (verbal and visual mental models). For example, organizing words may involve creating a cause and effect relationship between the selected words. Finally, the learner makes connections between the two models (verbal and visual mental models) that have been created by integrating “the organized information to other familiar knowledge structures already in memory” (Mayer, 1997, p. 5). The process on integrating involves “mappings” of the various visual and verbal representations. The ECT utilized animations, graphics and texts (on-screen or narrated text) to present the electric circuits units to the students. Learning from the tutorial followed Mayer’s highlighted above – selecting verbal and visual materials, organizing into a coherent representation, and making referential connections.

2.2.3 Balancing the input from audio and visual channels

This section is a description of the rationale for balancing the input from both audio and visual channels in the narrated text version of the ECT consistent with Mayer’s generative theory of multimedia learning. According to Mayer’s (1997) generative theory of multimedia learning, meaningful learning occurs when adults select relevant information in each store (visual or auditory), organize the information in each store into a coherent representation, and make connections between corresponding representations in each store. However, when one channel is loaded (unbalanced input), as shown in figure (3a) below, high mental effort associated with high cognitive load is expended to understand difficult and unfamiliar tasks (Mann, Newhouse, Pagram, Campbell & Schulz, 2002). Similarly, when the input is balanced from both channels (audio and visual), as shown in figure (3b) below, normal mental effort associated with normal cognitive load is required to comprehend the material (Mann *et al.,* 2002).

In order to avoid overloading one channel in the ECT, the integration of different multimedia resources (sound, graphics, on-screen text and animations) was carefully planned. Details of the integration of the different media are presented in the Electric Circuits Tutorial in Appendix K. Each content description in the narrated-text version, temporal speech cueing version, and the on-screen text version of the tutorial was supported by graphics, and animations where applicable.

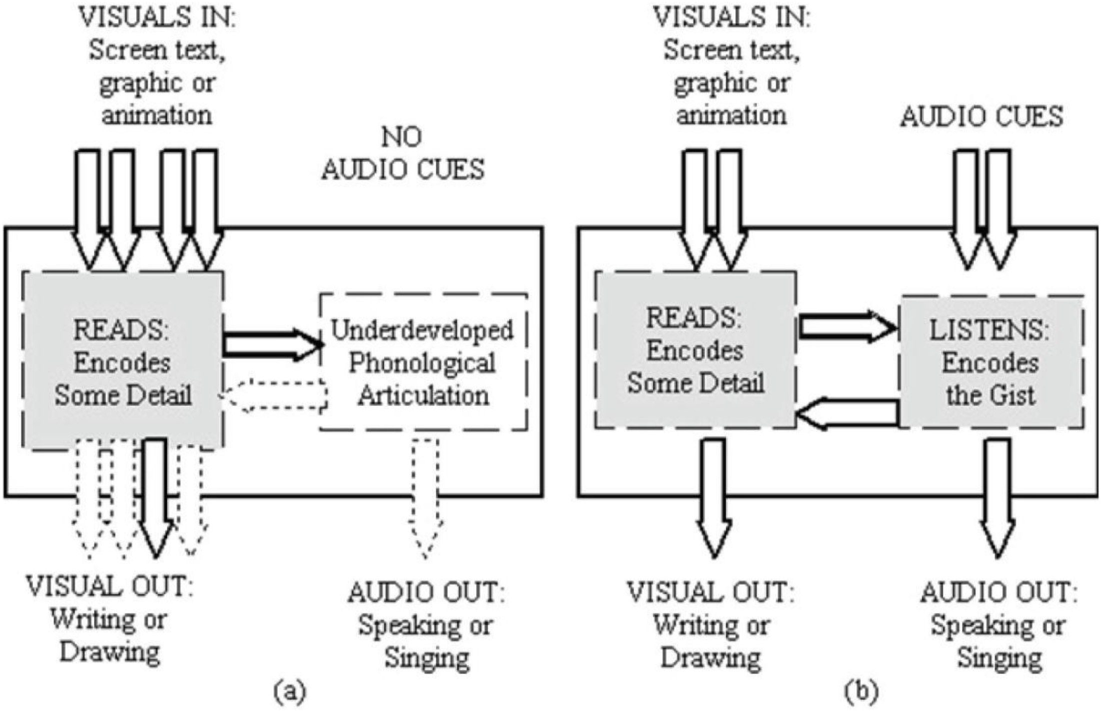

Figure 3. Two models of attention on a difficult or unfamiliar task (Mann, Newhouse, Pagram, Campbell, & Schulz, 2002).

2.2.4 The SSF Model of instructional design

Various design guidelines for multimedia instruction were identified in Mann (2008). He noted that these guidelines could be influenced by the designer's definition of multimedia or his/her opinion of how students interact and learn from multimedia. Of all the guidelines identified, the Structured Sound Function (SSF) model is of particular importance in the design of the speech cueing version of the ECT because it prescribes how sound should be integrated in multimedia learning materials. According to Mann (2008), the SSF model was designed as a guideline for the instructional designer or teacher who wishes to incorporate speech cues into instruction in order to be able to control students' attention. Mann (2009) pointed out that the function of the SSF is to give certain aspects of the visual a particular effect. The SSF model is based on the Attentional Control Theory of Multimedia Learning (ACTML).

According to Mann (2008), the SSF model prescribes five functions and three structures (shown in the table below) for combining speech with visual effects. From all the functions identified, the temporal speech cue was adopted for the design of the speech cue version of the ECT in this dissertation research. This is because the purpose for which sound was used was to act as a cue (such as, signaling the beginning of an event, providing a hint, providing partial answers, or focusing the attention of the student to a particular event). Below is a table showing the various sound functions and structures in the SSF model. Only the first function, the temporal speech prompt shown in table 2, was adopted for this dissertation research.

Convergent temporal speech cueing ("temporal cueing") from the Structured Sound Function (SSF) model of instructional design was adopted for its particular method of cueing sound (Mann, 1992, 1995, 1997, 2006). "Temporal cueing" is different from instructional text and narrated text because: 1) a statement is included justifying that the content is always on the school or college curriculum to be learned by the participants in the study; 2) the temporal speech cue sets a stage or signals a specific behaviour (Burton, Moore & Magliaro, 2004) with a brief spoken instruction, direction, hint, partial answer, reminder, or caution, not an oral report; 3) the research design in convergent temporal speech cueing is a repeated measures or time-series pretest-posttest-delayed posttest to examine forgetting, and a covariate included to assess the degree of prior knowledge in each treatment condition; 4) “retention” is always operationalized as the score on a test of the content to be learned administered immediately following the experimental treatment, “knowledge transfer” is a score on a delayed post-test which is included to test the content of long-term memory over time, consistent with the attentional control theory of multimedia learning, which links focusing attention with their long-term memory.

Table 2

Structured Sound Functions model for designing the modality of instruction (Mann, 2008)

	< Structuring the sound with a visual event >		
< Giving the sound a function >	*The Goal:* is convergent or divergent	*The Constancy:* is continuous or discontinuous	*The Density:* is massed, spaced or summarized
A Temporal Prompt: that cues that counterpoints that dominates that undermines	Continuous Convergent Temporal Sound Cueing during difficult tasks or with unfamiliar items can focus student attention on the critical visual events		
A Point of View: objective, subjective, performer, political, socio-cultural			
Locale: real, imaginary			
Atmosphere: feeling, mood			
Character's: past, future, personality			

The convergent temporal speech cueing from the SSF model, which is an instructional design model, (Mann, 1997) shown in the table above was adopted for this dissertation research. First, the sound was given a function of temporal prompting in the ECT design and then given a convergent structure. In this regard, the sound performed the function of helping students focus their attention on critical and important concepts. Mann (1997) noted that selecting a convergent goal for a temporal sound can help the student to shift his or her attention to a visual event.

2.3 Simulations in multimedia instructional materials

It is a common belief that Physics is one of the most abstract and difficult subjects to learn. And by extension, it is regarded as a subject in which only students with special aptitude for science and mathematics can ‘do well’ (Rieber, Tzeng & Tribble, 2004). However, technology offers the chance to change the general perception of who can or should learn Physics (White & Frederiksen, 1998). Studies have shown that computer simulations can make complex domains such as that of electric circuits accessible for students of varying ages, abilities, and learning levels (White & Frederiksen, 1998). Furthermore, tutorials with built-in simulations have been found useful in helping learners further their understanding of Physics concepts (Fiolhais & Trindade, 1998).

Therefore, in designing the Electric Circuits Tutorial for this dissertation research, computer simulations were incorporated to help students visualize those phenomena that may otherwise be difficult to represent graphically, for example, the movement of charges in a circuit. Similar studies, for example, Trey and Khan (2008) found that “using computer simulations in instructional contexts” (p. 519) gives students the opportunity of increasing their understanding of those phenomena that they cannot ordinarily see in the real world. Trey and Khan (2008) studied the effect of computer-based analogies on students' learning Le Chatelier's Principle and found that there was a significant relationship between instructional computer simulation and the achievement of students. Students who were taught using the computer simulations performed better in the posttest (90%) than those taught (68%) with non-analogical computer simulation. This result indicates the effectiveness of computer simulations when combined with other modes of instructional strategies such as analogies.

Park, Khan and Petrina (2008) studied the effect of computer simulations in science education on the achievement of Korean middle school students, and found significant difference ($t(233) = 2.401$, $p = 0.017$) in the achievement level of the control and experimental class. Students in the experimental group performed better after CAI was implemented in their class while there was no statistically significant difference in the achievement level of the control group in pre- and post-achievement tests (Park *et al.,* 2008).

Other studies have focused on the use of computer simulations in science teaching and found positive effects in achievement. Rotbain, Marbach-Ad and Stavy (2008), for example, focused on the use of computer animation to teach high school molecular biology, found significant difference in the achievement level of the experimental and control groups in the various sub-topics covered by the study. The experimental group performed better than the control group suggesting that the computer animation resulted in better conceptual understanding. Rotbain, Marbach-Ad and Stavy (2008) showed that computer animation "can help students to visualize the abstract concept and processes of molecular genetics by representing the subject matter in a more concrete manner" (p. 54).

Similarly, Jimoyiannis and Komis (2001) provided supportive evidence that the use of computer simulations in teaching and learning concepts of velocity and acceleration in projectile motion was effective in raising students' achievement. The authors reported a statistically significant difference in performance between those students who engaged with the simulation software and those who did not. In the study, both the control and experimental groups were exposed to traditional classroom instruction and the experimental group was exposed to computer simulations developed by *Interactive Physics* in addition to the traditional instruction. Specifically on electric circuits, Zacharia (2007) found that combining virtual and real experimentation in electric circuits enhances students' conceptual understanding. His study focused on undergraduate pre-service elementary school teachers attending a semester-long physics course.

In a related vein, a Nigerian study by Gambari, Ezenwa and Anyanwu (2014) showed that integrating animation with text and animation with narration (in accordance with Mayer's cognitive theory of multimedia learning) in a computer-based multimedia environment, enhanced Nigerian students' learning in mathematics. Computer-Assisted Instruction (CAI) that incorporated animation with narration, animations and text, reduced low achievements in solid geometry (Gambari, Ezenwa and Anyanwu, 2014). However, other research evidence shows that animations are more superior (in aiding learning) to static graphics (Mayer, Hegarty, Mayer & Campbell, 2005). de Koning, Tabbers, Rikers and Pass (2007) suggested that animations should be designed with visual cues. The authors reported that animations designed with visual cues were found to enhance learners' comprehension and transfer performance, in their study, which examined how learners' attention could be focused when learning from animation. 40 undergraduate psychology students viewed an animation of the cardiovascular system. The group that studied the animation with visual cues performed better in the comprehension and transfer test than the group that studied the animation without visual cues. However, in most of the research reviewed above, the animations or simulations as the case may be did not include speech cues.

2.4 The use of sound in multimedia learning

Sound, presented as narration or temporal speech cues as opposed to 'text', is received as a stimulus through the auditory system. Historically, the use of sound in multimedia learning materials received little attention until the "technological barriers that had prevented the full integration into all types of computer software were overcome in the early 1990s" (Bishop & Sonnenschein, 2012, p. 1). This is not to say that sounds in its various forms ─ voice, music, and environmental sounds ─ have not been recorded before the 20th century (Bishop & Sonnenschein, 2012).

More recently, the uses and functions of sound in multimedia have gained widespread attention among instructional designers, multimedia researchers, and educational psychologists. Mayer and his colleagues (1997) while trying to examine the methods that may be used to improve students' understanding of scientific explanations, proposed ten principles of multimedia learning which are based on a generative theory of multimedia learning (Mayer, 1997). These principles include the coherence principle, signaling principle, redundancy principle, spatial contiguity principle, temporal contiguity principle, segmenting principle, pre-training principle, modality principle, personalization principle, and voice principle

Generally, sound has been recognized as a means of conveying information in products and entertainment. For example, sound is used in computer and cell phone apps, in video games, and other interfaces. Specifically, in multimedia applications, "auditory cues can help a user to orient themselves, increase a sense of presence or, compensate for poor visual cues (graphics), increase task performance, and add enjoyment and immersion" (Collins & Kapralos, 2014, p. 1). Sound performs a number of functions in multimedia ─ gaining attention, focusing and holding our attention, activating existing images and schemas, engaging a learner's interest over time, and providing a reading context (Bishop, 2012; Mann, 2012).

There is empirical evidence that sound cues improved students' learning in school-aged children and adults (Mann, 1988, 1994, 1995, 1997), but not with adolescents in Eastern Canada (Mann, Schulz, Cui & Adams, 2012) or Western Australia (Mann, Newhouse, Pagram, Campbell & Schulz, 2002). Similarly, narration combined with graphics/animation has improved students' performance in problem-solving transfer questions better than on-screen text combined with graphics/animation (Mayer, 1997). For example, Adegoke (2011) examined the effect of multimedia instruction on senior secondary school students' cognitive achievement in physics. There were three experimental groups (animation + on-screen text, animation + narration, animation + on- screen text + narration) and a traditional lecture method served as the control group in the study. Adegoke (2011) reported that the animation + on-screen text + narration group outperformed the other groups, consistent with the findings of Moreno and Mayer (2000).

On the other hand, Gambari, Ezenwa and Anyanwu (2014) conducted a study on the effects of two modes of computer-assisted instructional package (Animation with Text and Animation with Narration) on students' achievement in solid geometry. The results of the study revealed that there was no significant difference in the mean achievement scores of students exposed to animation and text (X = 65.38) and those exposed to animation and narration (X = 73.80). Although the Gambari, Ezenwa and Anyanwu's (2014) study was consistent with Mayer's modality principle of multimedia learning, the statistical difference between the groups was non-significant suggesting that studies on Mayer's principles have also shown mixed results.

Other research studies have shown reversed modality effect (Witteman & Segers, 2010; Inan, Crooks, Cheon, Ari, Flores, Kurucay & Paniukov, 2015). Reversed modality effect is a condition whereby the participants in the on-screen text with animation group outperform participants in the narration with animation group (Tabbers, Martens & van Merrienboer, 2004). Witteman and Segers (2010) reported that they found a reversed modality effect for transfer questions, that is, the scores in the reading condition were higher than the scores in the listening condition at Time2 (B = 0.614, P = 0.024) but not at Time1 (B = -0.208, P = 0.451). Similarly, Inan et al. (2015) reported that the multivariate analysis of variance “yielded significant multivariate effects for modality (Wilks $\lambda = .769$, $F(4,146) = 10.976$, $p < .001$)” (p. 127). That is, for all the four dependent variables, participants in the written text group outperformed participants in the spoken text group.

2.5 Modality in multimedia learning

In order to review the literature on modality in multimedia learning, it is important to distinguish between delivery media, presentation modes, and sensory modalities. Mayer (1997), defined delivery media as “the system used to present instruction, such as a book-based medium versus a computer-based medium” (p. 1). In this research, the delivery medium was a computer-based medium. The Electric Circuits’ Tutorial (ECT) was ‘loaded’ on the hard drive of the computers from where it was run. Mayer went further to say that presentation modes refer to “the format used to represent the presented instruction, such as words versus pictures” (p. 1). In this research, the presentation mode was a combination of sound, graphics and on-screen text. Concerning sensory modalities, Mayer says “sensory modality refers to the information processing channel that a learner uses to process the information, such as acoustic versus a visual information processing” (p. 1). In this research, the sensory modality in the on-screen text version of the ECT was the visual channel while the sensory modality for the narrated text version and the temporal speech cues version was a combination of acoustic and visual information processing channels.

According to the modality principle (Mayer, 2001; Mayer & Moreno, 1998), also referred to as the modality effect (Sweller, van Merrienboer & Paas, 1998), when giving a multimedia explanation, words should be presented as auditory narration rather than as visual on-screen text; that is, words should be presented auditorily rather than visually. Mayer & Moreno (1998) used 137 college students divided into six groups ─ (viewing the animation and listening to the narration or viewing the animation and reading the on-screen text whether concurrently or sequentially). The authors found that irrespective of the order of presentation, the groups that were presented with the verbal information auditorily whether sequentially or concurrently outperformed those that read the on-screen text concurrently with the animation or sequentially after the animation.

The results of research on the modality effect in multimedia learning shows that using spoken rather than written instruction to accompany graphics and animations aids learning (Mayer, 2009). A meta-analysis conducted by Ginns (2005) found convincing empirical evidence for the modality effect. Recently however, research has shown the conditions under which the modality effect reduced. The modality effect diminished when learners were allowed to control the pacing of the multimedia instruction (Tabbers et al., 2004; Witteman & Segers, 2010) or once longer texts were used in the multimedia instruction (Rummer, Schweppe, Furstenberg, Scheiter & Zindler, 2011).

In the real world, we often coordinate information from two or more sense modalities at the same time, known as “cross-modal attention” (Eysenck & Keane, 2015, p. 183). Cross-modal attention or “the coordination of attention across modalities, namely vision and audition” (Eysenck & Kean, 2015, p. 716) was the focus of this research.

2.6 Formative evaluation of instruction

Designing and conducting formative evaluations is one of the processes involved in the instructional design life cycle. It is important to note however, that formative evaluation does not imply assessing student learning but has as its central purpose “the collection of data and information during the development of instruction that can be used to improve the effectiveness of the instruction” (Dick, Carey & Carey, 2005, p. 277). Tessmer (1993) viewed formative evaluation as a “judgment of the strengths and weaknesses of instruction in its developing stages, for purposes of revising the instruction to improve its effectiveness and appeal” (p. 11). He went further to say that formative evaluation is a “cost-saving measure to economically 'debug' instruction and increase client satisfaction” (p. 13).

The formative evaluation process involves gathering data from reviewers to answer questions that one may or may not have had about the instruction (Dick et al., 2005). According to Dick et al., (2009), the formative evaluation component of the instructional design process is not a philosophical or theoretical approach, but rather about the instructional effectiveness of the materials and the review that should follow. Although the steps of a formative evaluation occur during the developmental stage of the instructional design process in most instructional design models (Seels & Glasgow, 1990), other formative evaluation authors recommend that it be placed within every step of the instructional design process (for example, the CAI design model of Hannafin and Peck,1988). Research has shown that instructional materials that were revised following a formative evaluation produced statistically significant gains in “student performance over the original, unevaluated versions of the instruction” (Tessmer, 1993, p. 13).

There have been various research conducted on formative evaluation which underscore the importance of formative evaluation in the overall instructional design process. For example, Ogle’s (2002) doctoral dissertation titled “towards a formative evaluation tool” highlighted the importance of evaluation in the instructional design process and specifically developed a formative evaluation tool that instructional designers and developers can use to formatively evaluate their instructional materials. Similarly, Nellman’s (2008) doctoral dissertation titled “a formative evaluation of a high school blended learning biology course” (p. 1) specifically involved formatively evaluating a genetics unit in biology course designed in a blended format (incorporating both face-to-face and distance education delivery methods). Nellman’s (2008) doctoral dissertation involved a pilot study and a main study. The author reported that the results of the research indicated that there were significant increases ($p<.05$) in content-understanding and problem-solving.

Two formative evaluation models that are widely used and widely cited in the literature are the Alessi and Trollip’s (2000) and the Dick, Carey and

Carey's (2014) formative evaluation models. Although there are other models of formative evaluation by various authors and scholars, these two models were used in this dissertation because of their compact nature and ease of adaptation. The stages of a formative evaluation are the quality review process; the pilot test of the instructional materials; and validation (Alessi & Trollip, 2000).

2.7 Self-explanation and multimedia learning

This dissertation was concerned with "scientific explanations" as described by Chi (1998). Mayer (1997) also described scientific explanations. However, Mayer's description of scientific explanations was concerned with "scientific explanations of cause-and-effect systems" (p.1). An older method of gauging learning process is Ericsson and Simon's (1993) concurrent verbalization or protocol analysis. Ericsson and Simon argue that verbalization does not affect task performance. However, there is clear evidence that certain kinds of verbal reports sometimes do, in fact, produce changes in task performance (Austin & Delaney, 1998).

The present dissertation adopted verbal data analysis (self-explanation) as opposed to Ericsson and Simon's (1993) protocol analysis because self-explanation is better suited for the dissertation. Self-explanation is used to capture participants' knowledge representation or to capture the mental model a participant has (Chi, 1997). However, protocol analysis is used to capture the processes of solving a problem by starting with a model of the task (an ideal template) and asks if there is a match between the path a participant follows and the ideal template (Chi, 1997). Protocol analysis is restricted because it does not allow for reflections, explaining or describing what a participant is attending to or doing.

Self-explanation has been described as “a domain general constructive activity that engages students in active learning” (Roy & Chi, 2005, p. 5). Those authors further stated that during the process of learning, learners are able to monitor their understanding as they engage in knowledge construction. However, in this research, self-explanation was used as a measurement protocol because the learning effect of self-explanation in itself was not measured. All the participants were given equal opportunity to self-explain during the validation and experiment therefore setting a baseline for comparison. Roy and Chi (2005) identified some cognitive processes involved in self-explaining: generating inferences, integrating information with the material and with prior knowledge, and monitoring and repairing faulty knowledge.

Roy and Chi (2005) highlighted the procedure that has been used in previous studies on self-explanation – ask learners to explain the meaning of a sentence and the researchers then code the learners’ verbal protocols. Studies such as the one by Chi, de Leeuw, Chiu and LaVancher (1994) which examined how students learned successfully from incomplete text materials and the one by Chi, Bassok, Lewis, Reimann and Glaser (1989) which described the steps involved in a worked-out problem example were the original studies that proposed self-explanation as a potential learning activity.

After that time, several studies have been conducted on self-explanation in various learning contexts and across various age groups.

Other bodies of research have examined the effectiveness of self-explanation on learning and found that learning gains and high-quality self-explanations are positively correlated (for example, Renkl, 1999). Matthews and Rittle-Johnson (2008) reviewed the literature on self-explanation and reported that even though self-explanation prompts were positively correlated with improved learning, learners usually generate different levels of self-explanation. The authors contrasted the effects of conceptual and procedural instruction on self-explanation quality and learning and found that “self-explanation prompts supported generalization of procedures” (p. 13). The authors also found differences in the quality of self-explanation in the procedural instruction condition (n = 21) and the conceptual instruction condition (n = 19). In another self-explanation study on “the effect of self-explanation and prediction on the development of principled understanding of novices learning to play chess”, de Bruin, Rikers and Schmidt (2006, p.1) found that participants in the self-explanation condition displayed superior understanding of the endgame principles in chess than the other two conditions (predicted and control groups).

Furthermore, self-explanation has been found to be an effective constructive learning activity. In a number of studies reviewed by Roy and Chi (2005), the summary was that “both spontaneous and prompted or trained self-explanations were associated with deep learning gains across a variety of domains, age ranges, and learning contexts” (p. 14). Similarly, the authors also reported that the results of research they reviewed showed that multimedia learning environments have been more *stimulating and supporting* to self-explanation than text-only learning situation. Roy and Chi (2005) classified self-explanation into high-quality self-explanations (comments reflecting deep analyses, inferences linking examples to text materials and to prior knowledge, more task-related ideas, monitoring understanding and making relationships explicit) and low-quality self-explanations (re-reading, paraphrasing, and overestimating understanding). Self-explanations were used merely as instrumentation for collecting verbal reports during the formative evaluation and experiment of the electric circuits' tutorial. The following section is a description of the theories of multimedia instruction applicable to the design of the three versions of the ECT - convergent temporal speech cueing, narrated screen text, and on-screen text.

2.8 Summary

Chapter two was a review of the extant literature in multimedia learning. The chapter examined previous research studies in multimedia learning by highlighting the role of multimedia and technology in learning, particularly in the science classrooms. Previous research has shown how instructors and instructional designers might include difficult or unfamiliar items in their online curricular materials to affect learning. This research deepens that work by applying results of psychological investigations to curricular materials. The chapter was also a review of the two theories of multimedia learning (Mayer's cognitive theory of multimedia learning and Mann's attentional control theory of multimedia learning) that formed the theoretical design frameworks of the three versions of the ECT. Furthermore, the chapter examined the structured sound function (SSF) instructional design theory that guided the design of the Electric Circuits' Tutorial. The SSF model prescribed how the convergent temporal sounds were used in the ECT, that is, as convergent temporal speech cues that hints, directs, provide partial answers, reminders, or cautions to the learners while the cognitive theory of multimedia learning (Mayer, 1997) described how the narrated screen text and on-screen text were integrated in the ECT.

Further, the suggestion from "balancing the input" was implemented in the narrated screen text and the on-screen text versions of the ECT to ensure that information entering both the audio and visual channels was balanced to minimize the mental effort required for the ECT. The ACTML is the core design theory on which the convergent temporal speech cues version of the ECT was based because the purpose of the ECT was to help below-average students to focus their attention on critical and important information.

Formative evaluation, which is an important stage in the overall instructional design process, was applied to the three versions of the tutorial. The literature on formative evaluation was reviewed to better understand its purpose in the instructional design life cycle. Also, previous studies that formatively evaluated their instructional media were examined in the literature. The general finding from the previous research work was that students performed better with instructional materials that were formatively evaluated than those instructional materials without formative evaluation. Self-explanations as a means of eliciting students' learning processes and as used in previous research were also discussed. It was noted in the chapter that even though self-explanation has been described as a constructive learning activity, it was used purely as a means of eliciting participants' verbal reports because investigating the learning effect of self-explanations was not the purpose of this research and therefore it was not measured.

3. METHODOLOGY

The purpose of this research was to determine which of the two guidelines of designing multimedia sound ─ narration or cueing ─ helps below-average high school Physics students in Ilorin, Nigeria to focus their attention on critical information in an electric circuits' tutorial. This chapter is a description of the research design, the education system in Nigeria, the senior secondary school (SSS) curriculum in Nigeria, and the methods adopted for the research. Furthermore, this chapter is a description of the participants in the research and how the samples were constituted**.** Although not specifically discussed in this chapter, information about ethics and ethical considerations for this research can be found in Appendix B.

3.1 Research Design

The research design used in this dissertation is a quasi-experimental repeated occasion pretest-posttest-delayed posttest method which involved three experimental groups - convergent temporal speech cueing group, narrated screen text group and on-screen text group. A quasi-experimental research design is an experimental design that does not meet all the requirements necessary for controlling influences of extraneous variables (Creswell, 2008). From this definition, it follows that the researcher may not be able to control some variables in the experiment in the same way as an experimental research where the researcher has control of the variables involved. For example, in an experimental research, the researcher may be able to allocate participants to various groups (experimental or control groups). This is not the case in a quasi-experimental research design. Quasi-experimental research designs can provide information about participants' changes and give a reliable picture of achievement before and after an intervention (Gribbons & Herman, 1997).

The research design adopted in this dissertation is captured in the chart below. This diagram represents the procedure that should be followed in an experimental design and has been adapted for this research. The first stage in an experimental design is to determine the target population out of which there could be a random sampling or consent to determine those that would be part of the experimental group. In this research, consent was sought from the schools that participated.

The stage which deals with randomized allocation of participants into groups was not applied in this research because the intention was to follow the school's programme rather than disrupt it in any way. Moreover, there was no control group in this research. All the three groups were experimental groups because they all participated in the validation and experiment with ECT. This procedure, as outlined by the World Health Organisation (2001), guided the research.

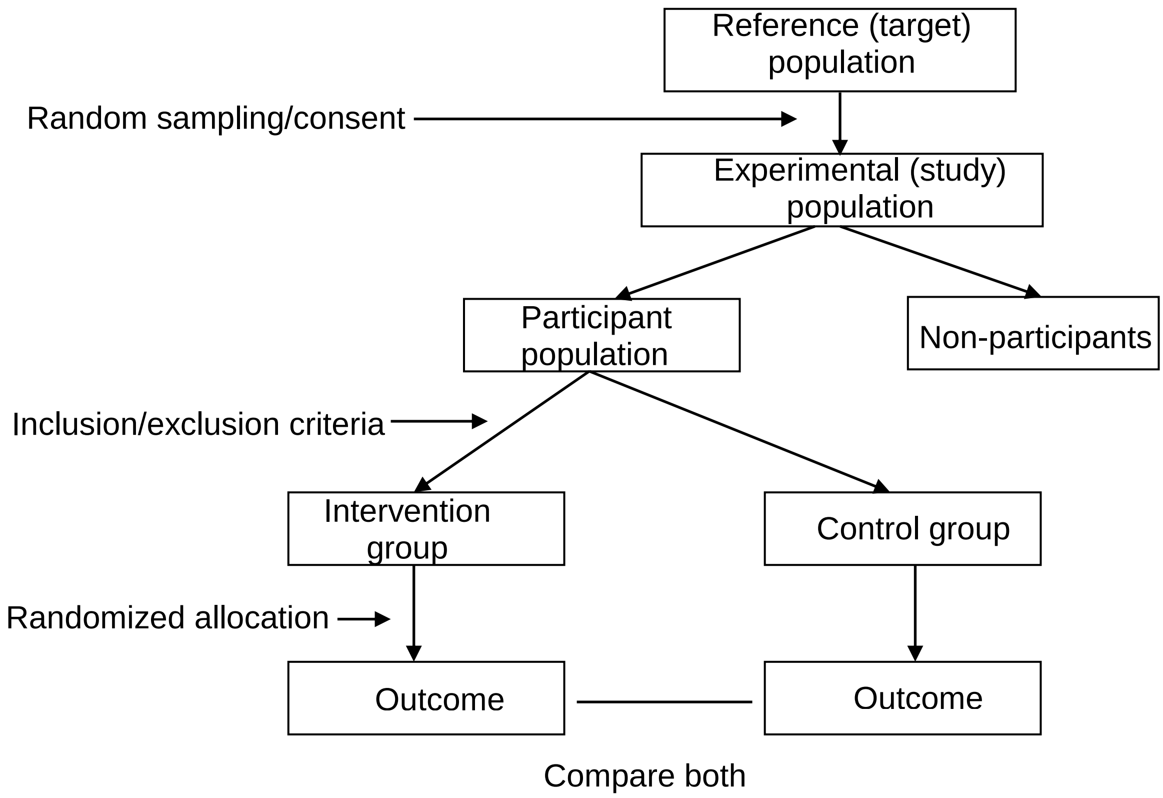

Figure 4: Procedure in an experimental research

Source: World Health Organisation (2001, p. 57)

3.2 Description of Secondary School Education System in Nigeria

The responsibility for educating the Nigerian child is shared among the three tiers of government; the federal, state and local governments. The federal government concentrates more on tertiary education, while the state governments are more directly involved with the secondary level and the local governments are largely responsible for primary education. The Federal Ministry of Education plays a major role in regulating the education sector in Nigeria by engaging in policy formulation and ensuring quality control.

The Nigeria National Policy on Education (NPE) stipulates that children of secondary school age who have completed six years of primary school attend secondary school for six years in two 3-year phases - the junior secondary phase and the senior secondary phase. The first level of high school education is the Junior Secondary School I to III (JSS I-III) equivalent to grades 7-9 (Junior High School) in North America and the second level is the Senior Secondary School I to III (SSS I-III) equivalent to grades 10-12 (High School) in Canada and the United States. The NPE recognises the establishment of secondary schools by the federal government, state governments, voluntary agencies, communities and private individuals.

Secondary school education in Nigeria is more or less a state affair similar to the provincial system of education in Canada. That is, each of the 36 states and the Federal Capital Territory in the Nigerian federation has control over their respective schools. In Kwara State, the public secondary schools are under the control of the Kwara State Teaching Service Commission, an agency with the responsibility of the employment of teaching and non-teaching staff, promotion, supervision, and standardization in the public schools.

3.3 Senior Secondary School Physics Curriculum in Nigeria

The Federal Ministry of Education (FME) in conjunction with the former Comparative Education Study and Adaptation Centre (FME and CESAC, 1985) developed the secondary school Physics curriculum in Nigeria. This curriculum, according to Omosewo (1998), was structured in a spiral form with similar contents in the senior secondary I, II and III (Grades 10-12), but with increasing cognitive demands and depth of coverage as students progress through the secondary school levels. The idea of spiraling curriculum was first developed by Bruner (1960), where information is structured from simple to complex, and revisited over time. For example, students in the Junior School are presented with simple electric circuits consisting of one or two resistors in series while those in Seniors Schools are presented with more complex electric circuits' analysis involving more than five resistors, in series or parallel.

The Physics curriculum is reviewed regularly because of its spiraling nature whereby the concepts taught at the lower grades form the foundation upon which the understanding of new knowledge at the higher level is built. The Nigeria National Policy on Education (2004) stipulates that the aim of Physics at the secondary school level is to develop essential scientific skills in the students so as to stimulate and enhance creativity in order to prepare them to apply their skills in technological development. The Nigerian Educational Research and Development Council (NERDC), the body that is currently responsible of reviewing primary and secondary school curricula, and the Federal Ministry of Education, reflect this objective in the Physics curriculum, which is constantly being reviewed.

3.4 Participants

Several criteria such as below-average performance, class/level in school, and prior knowledge, were used to determine the participants.

3.4.1 Description of the participants

Participants were Senior Secondary School 2 (SSS2) students (11^{th} graders) attending Physics classes in four secondary schools in the Ilorin metropolitan area of Kwara State, Nigeria. One hundred and twenty (N = 120) students were selected from the four schools in Ilorin metropolitan area to participate in the research. The selection of participants was based on those with below average performance in Physics as determined by participants' previous academic records provided by their teachers. Below average performance, as described in the definition of terms in Appendix A, refers to those students who attain a term score that was less than the class average. This criterion was chosen in order to have participants with a comparative ability level because the class average for each school was different.

3.4.2 Participants' characteristics

The participants were all students from a homogeneous population in that they had all completed Integrated Science up to grade 9 and passed with a minimum grade greater than 50 per cent. There were more males than females in the research (66 males and 54 females). The ages of the participants ranged from 15-17 years (Mean age = 17.8; SD = 2.74). The participants were all attending grade 11 (SSS 2) having one year before they write their final West African Senior Secondary Certificate Examination (WASSCE). It is a prerequisite to pass Integrated Science in the junior secondary school in order to offer Physics in the senior secondary school, therefore, the participants in this research have prior knowledge in electric circuits, which is one of the topics in the Physics syllabus.

Table 3 below summarizes the characteristics of the participants in this research. In order to arrive at these participants' characteristics, each item was determined by the criteria stipulated. That is, using the Computer Attitude Inventory in Appendix D, and other past records provided by the physics teachers.

Table 3

Participants' characteristics chart based on DECL (Mann, 1997) adapted from Alessi and Trollip (2001)

Item	Participants
Age	15-17 (Mean age = 15.8; SD = 2.74)
Gender	Male = 66, Female = 54
Education level	Junior School Certificate Examination (JSSCE) pass in integrated science
Reading level	As determined by interviews with the Physics Teachers
Motivation	As determined by Yee's (2006) survey on motivation
Prerequisite knowledge and skills	Basic mathematics and workings of simple electric circuits as determined by a pass in the

(table continues)

	Junior Secondary Certificate Examination in Integrated Science
Browsing and typing with a computer	As determined by Loyd and Gressard's (1984) Computer Attitude Scale
Access to computers	As determined by the Computer Use and Attitude Inventory (Jones & Clarke, 1994; Francis,1993; Loyd & Gressard, 1984; Christensen & Knezek, 1996; Sam, Othman & Nordin, 2005; Yee, 2006)
Engagement	As determined by the Computer Use and Attitude Inventory containing items adapted from the Game Engagement Questionnaire (Brockmyer, Fox, Curtiss, McBroom, Burkhart & Pidruzny, 2009)
Typing ability	As determined by the assessment results provided by the Computer Studies Teachers at the four participating schools
Ability in Physics	Below average as determined by performance in previous assessment results provided by the Physics Teachers at the four schools in the dissertation research

Below-average performance was a precondition for participation in this research, in accordance with the individual differences principle (Jonassen & Grabowski, 1993; Barrett, Tugade & Engle, 2004). The individual differences principle describes a learning outcome wherein design effects are strongest for low prior knowledge learners and hardly present for high prior knowledge students (Mayer, 2001). Below-average entry behaviour was considered a necessary requirement to prevent the occurrence of expertise reversal effect (Sweller, Ayres, Kalyuga & Chandler, 2003), which has been described as "the reversal of cognitive load effects with expertise" (p. 23). Paas, Renkl and Sweller (2003) described the expertise reversal effect as a learning outcome in which an instructional technique that is effective with below-average students loses some of its effectiveness and even becomes ineffective with average and above-average students.

Although the participants in this research had been introduced to electric circuits in previous grade levels (previous years) as a result of the spiraling nature of the curriculum, none of the participants had been introduced to electric circuits immediately before or during the experiment. The participants had not also been exposed to educational multimedia in the school setting, neither have they seen a Physics tutorial in electric circuits.

To determine prior knowledge in this research, an instrument was adapted from Engelhardt and Beichner (2004) and pilot tested with twelve (12) students. Prior knowledge is an important factor in multimedia learning research (Mayer, 1997), where multimedia effects and contiguity effects were found to be strongest for low prior knowledge learners, and hardly present for high prior knowledge learners.

There were two occasions where stratified random sampling technique was implemented in this research. Stratified random sampling was used "to control for factors that may influence learning", as described in Leedy and Ormond (2001, p. 215). Using the stratified random sampling technique, participants were assigned to one of the three groups – (temporal speech cueing, narrated screen text, or on-screen text groups) described above. The stratified sampling was based on gender, perceived modality preference on the auditory-visual-kinesthetic learning style and attitudes towards using computers as determined by the Computer Use and Attitude Inventory from various authors as shown in Appendix (D). By identifying the categories, stratified random sampling helped to ensure that characteristics of the population were present in the three groups in the sample, thereby reducing the standard error.

3.4.3 Sampling of participants for the research

Sampling for the quality review: From the 120 participants selected for the study, twelve (12) were randomly assigned to the stratified groups based on their gender, perceived modality preference and low scores in the pretest to participate in the quality review. This group of twelve participants was not involved in the pilot and validation stage of the three versions of the tutorial in order to mitigate the prior knowledge advantage that they may have over other students involved in the validation stage. Additionally, four Physics

Teachers, one from each of the selected schools, and one instructional designer participated in the quality review.

Sampling for the pilot test: From the 120 participants selected for the study, twelve (12) participants were randomly assigned to the stratified groups based on their gender, perceived modality preference and low scores in the pretest to participate in the pilot test. Similar to the quality review stage, these 12 participants were not involved in the validation stage of the study in order to mitigate the prior knowledge advantage that they may have over other participants in the validation stage.

Sampling for the validation: From the remaining 96 participants in the population for the study, 51 grade 11 students with below-average physics scores from the four secondary schools were randomly assigned to one of three groups ─ temporal speech cueing, narrated screen text, or the on-screen text version. 51 participants showed up for the validation, the other 45 participants were not available for the experiment. The validation stage required these 51 participants to self-explain as they used the Electric Circuits Tutorial, consistent with (Chi *et al.*, 1989; 1991).

3.5 Participating Schools

Several factors were used to determine the schools' appropriateness for inclusion in this dissertation research. First and foremost, the four schools were chosen for the research based on their ownership structure as the ownership structure, by and large, is a determinant of how resourced the schools were. Second, these particular schools were selected because, although they represent a mix of private and public schools, they are all low fee-paying in an average socio-economic area. The researcher approached the schools to seek consent to participate in the research. The researcher obtained approval to conduct research and letters of introduction from the Kwara State Ministry of Education. The letter of introduction was taken to the four schools described below:

- In 2014, School A was wholly owned by a university in the Ilorin metropolis. It was a mixed school (boys and girls), with non-residential status.
- School B in 2014, was owned by the Kwara State Government. It was the oldest secondary school in the Ilorin metropolis having been established in 1914. It was a boys' only school with a population of 650 students living in the school (wholly boarding).
- School C in 2014, was a private school, established in 2003. The school, which started with 22 students when it was established, currently has a population of about 400. It was a mixed school with compulsory boarding.
- School D in 2014, was also previously a Catholic missionary school, established in 1968, whose affairs and running had been taken over by the Kwara State Government. It was a mixed school with a population of 2500 students (day only).

Table 4 below shows a summary of the schools, participants, and chronology of the research.

Table 4

Schematic representation of school types, number of participants in the sample and the design of the research

School	Type	Number in the sample						
		Participants (Age range 15-17 years)						
		Survey	quality review	Pilot test	Pre test	Validation/Experiment	Posttest	Delayed posttest
School A	Private School	30	3	3	18	18	18	18
School B	Public School	30	3	3	3	3	3	3
School C	Private school	30	3	3	12	12	12	12
School D	Missionary school	30	3	3	18	18	18	18
Total		120	12	12	51	51	51	51

3.6 Measure and instruments

A pretest (Appendix H), including 20 multiple-choice items adapted from Determining and Interpreting Resistive Electric Circuits Concepts Test (DIRECT) (Engelhardt & Beichner, 2004), was administered to measure participants' knowledge about electric circuits. Each item in the pretest was scored 5 points for a correct answer or 0 point for an incorrect answer. Therefore, a maximum of 100 points can be achieved in the pretest.

Engelhardt and Beichner (2004) established the validity and reliability of the instrument. These authors reported that the Kuder–Richardson formula 20 (KR-20) was used to evaluate the reliability. They reported reliability level was 0.70. These authors also reported that content validity was established by "presenting the test and objectives to an independent panel of experts to insure that the domain was adequately covered" (p. 103).

There were 20 items in the posttest, the same as in the 20 items in the pretest, to determine participants' attentional focus on the electric circuits' tutorial. The posttest and delayed posttest had the same format and followed the same scoring procedures as the pretest, but the questions in the posttest and delayed posttest were re-ordered. The posttest was administered immediately after the intervention while the delayed posttest was administered six weeks after the intervention.

3.7 Software and materials used for the research

The materials for this research were developed with an authoring program called Adobe Captivate 5.5 (Adobe, 2013), which is well suited to this task because it can produce multimedia materials. Adobe Captivate has been described as an “eLearning authoring software for creating and maintaining interactive eLearning content” (Adobe, 2013). It has been found to be easy to learn, and can be made to produce aesthetically pleasing screen and sound designs. Table 5 below shows a list of software and instructional materials used in the research.

Table 5

List of the software and materials used for the research

Material/software	Purpose/use
Adobe Captivate	Used by the investigator to design the multimedia tutorial (ECT)
PhET Circuit Construction Kit (CCK) interactive simulation (PhET, 2013)	Used to simulate DC & AC circuits (used by the participants to create DC circuits.
Workbook	Used to make notes and solve electric circuits problems
Calculator	Used by the participants for mathematical computations

Figure 5 shows how the materials and equipment were arranged for the participants in the research.

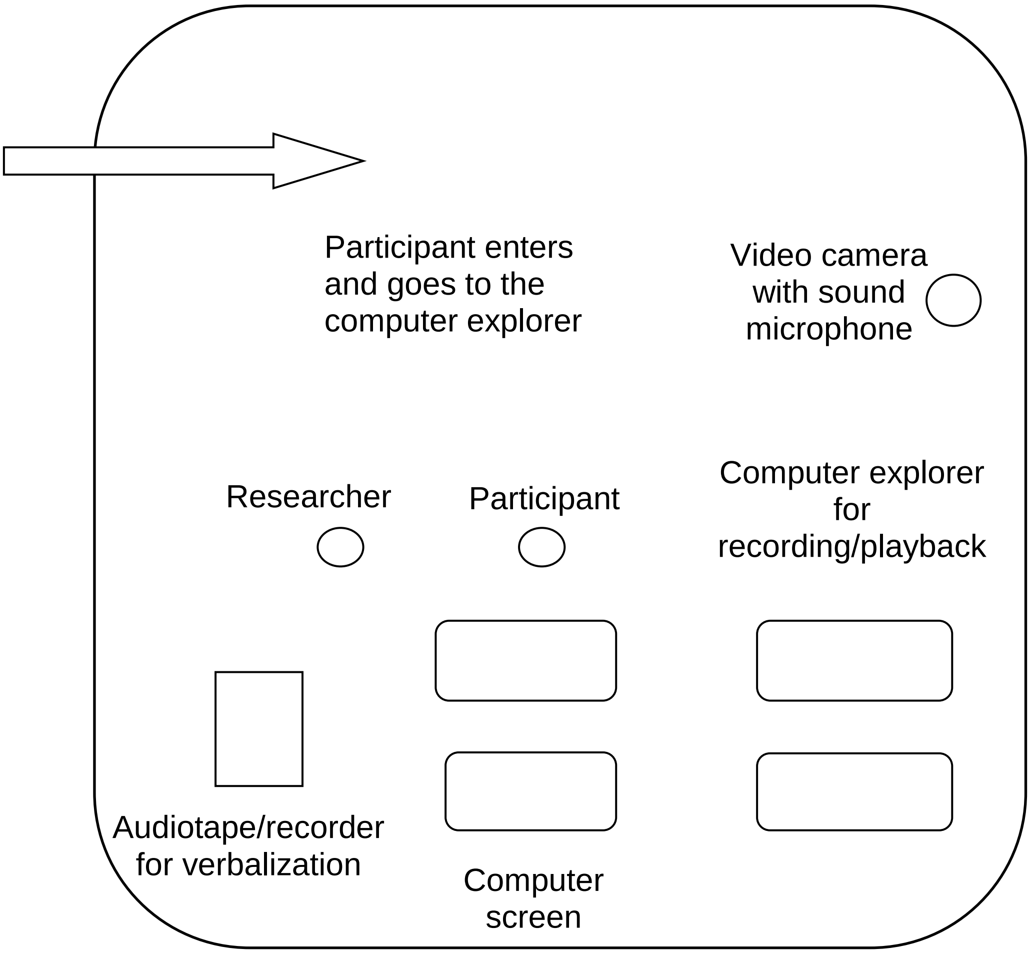

Figure 5. Arrangement of the equipment in the Explorer Centre

Figure 5 above shows the arrangement of the equipment used in all the stages of the formative evaluation. A video camera captured audio and visual images of the participants during the research. An "explorer centre" was used by the participants for the tutorial. Mann (1996) defined an Explorer Centre as "individual computer/video workstations with a computer and microphone linked to a videotape recorder" (p. 1). An audiotape recorder was used to record the sound and verbal protocols of the participants. The role of the participant was to self-explain while using the electric circuits' tutorial. The researcher interacted with the participants and encouraged them to keep self-explaining while using the electric circuits' tutorial.

3.8 Summary

This chapter was devoted to the methodology of the research. It was described that the secondary school education in Nigeria was mostly controlled by the state, although there are private and missionary schools. It was discussed in the chapter how the secondary school curriculum in Nigeria was structured in a spiral form to allow the students get an early introduction to the topics that will be expanded on in later years. The chapter was also a detailed description of the research design and the methods adopted in the research to gather data. Moreover, the chapter was a description of the participants in the study and highlighted how the samples were constituted, 120 participants were chosen to be a part of the research. The participating schools and the criteria adopted for selecting the schools were also described. Four schools were selected to participate in the research, a university-owned school, a private school, a government-owned school, and a missionary school. Finally, the materials /software used in the research and how they were setup in the "explorer centre" were described.

The next chapter of this dissertation is a description of the design and development of the three versions of the electric circuits tutorial (ECT). Although, the ECT was part of the materials used for the research, the researcher decided to create a separate chapter for the design and development to ensure clarity.

4. DESIGN AND DEVELOPMENT OF THE ELECTRIC CIRCUITS' TUTORIAL

Chapter four of this dissertation is a description of the design of three versions (convergent temporal speech cueing, narrated screen text, and on-screen text) of a tutorial on Electric Circuits for below-average Physics students in Ilorin senior secondary schools (SSS). This chapter is devoted to the design and development of the ECT because the materials design involved extensive work and it is appropriate to document the design in a separate chapter for clarity. The full on-screen text version of the ECT can be found in Appendix K.

4.1 Design of the three learning environments

Three multimedia learning environments on the curricular topic, “electric circuits”, were developed specifically for this research: “Temporal Cueing”, “Narrated Text”, and "Instructional Text" (“Text”), All three versions had graphics. Adding a graphic to text can improve learning, according to the multimedia principle (Mayer, 2005).

“Instructional Text” (“Text”), also known as “multimedia text” (Vaughn, 2014), “written text” (Mayer, 2005), or “on-screen text” (Kalyuga, Chandler & Sweller, 2004), is one of the most important elements of multimedia (Vaughn, 2014). “Text”, in this research was defined as instructional information and feedback that used first and second rather than third person, and directly addressed the reader, in accordance with research by Ginns, Martin and Marsh (2013).

"Narrated text", also known as "narrated screen text" (Bishop, Amankwatia & Cates, 2008), "auditory text" (Kalyuga, Chandler & Sweller, 2004), "spoken text" (Sabet & Shalmani, 2010), and "oral text" (Segers, Verhoeven & Hulstein-Hendrikse, 2008), or "Speech Cues" (Mayer, 1997; Moreno & Mayer, 1999) featured a learning environment with graphics and a balance of spoken and on-screen information. In psychological terms, narrated text balances verbal and nonverbal representations in a students' working memory by weeding and off-loading information from the visual events into the sound channel (Mayer, 2001, 2003) consistent with Paivio's dual coding theory (Sadoski, Paivio & Goetz, 1991). Mayer used the term "weeding and off-loading" to characterize the process of taking information from one channel (visual channel) and distributing to the other channel (verbal/acoustic channel) in order to balance the load. The dual coding theory proposes that humans have separate systems for representing verbal and non-verbal information (Paivio, 1986). In educational terms, "narrated text" can be characterized as an oral report (Mann, 1997). The narrated text condition had represented the status quo in multimedia learning research for over twenty years.

The design of the three versions of the ECT involved instructional analysis so as to identify the skills that the learners need in order to achieve the intended learning objectives. The other stages involved the development of the visuals and audio for the ECT.

4.2 Instructional Analysis and Learning Objectives

The instructional analysis of the research examined what is to be learned, as well as the students' competence. The subject matter expert identified the areas students find challenging during instruction, therefore, more emphasis was laid on these areas.

The Design Phase

Develop initial content ideas: The content ideas for the physics tutorial were based on the Nigerian physics curriculum developed by the Nigerian Educational Research and Development Council (NERDC) in conjunction with the Federal Ministry of Education. Content areas were matched with the requirements of West African Examinations Council (WAEC) (2008) as stipulated in the senior secondary school syllabus. The researcher collaborated with subject matter experts to identify specific areas of challenge in electric circuits in order to determine where emphasis should be laid to be able to assess the learning processes of the students from the three versions of the ECT. The following units were identified as the areas in electricity required for coverage by the West African Examinations Council (WAEC) (2008) syllabus. Those units in **boldface** were identified as challenging topics for the learners.

Unit 1. Electric current, electromotive force (emf), potential difference (pd), resistance, electric charge, time, quantity of electricity, (their definitions, units and relations and calculations)

Unit 2. Instruments used for measuring current, potential difference,

Unit 3. Circuit symbols and diagrams

Unit 4. Ohm's law and calculations

Unit 5. Experimental verification of Ohm's law

Unit 6. Arrangement of resistors in series and in parallel and calculations

Unit 7. Resistivity and conductivity and calculations

Unit 8. Factors affecting resistance of a wire

Unit 9. Arrangement of cells in series and in parallel

Unit 10. Terminal potential difference, Internal resistance of a cell, current, external resistance and the equation connecting them and calculations

Unit 11. Electrical energy and electrical power and problems

Unit 12. Buying electrical energy, house wiring including advantages of house wiring in parallel over series wiring

However, the ECT was only on unit 6 (arrangement of resistors in series and in parallel and associated calculations) because it was the unit featured mostly in examinations. Furthermore, time constraint was considered when deciding on which topic the ECT would target because the tutorial was designed to last for about 60 minutes. Also of importance during this stage is the identification of those learning outcomes that the tutorial will target. The learning outcomes and the order of presentation of the materials were discussed with the subject matter experts. The ECT utilized the following structure:

- Interactive questions on circuit analysis
- Simulate direct current circuits and the student to build their circuits
- Challenge to diagnose incorrect circuit connection
- Connect a virtual electric circuit using the PhET circuit construction kit
- Give feedback to engage the students on the questions

Figure 6 below shows the arrangement of the units in the electric circuits' tutorial (arrangement of resistors in series and in parallel).

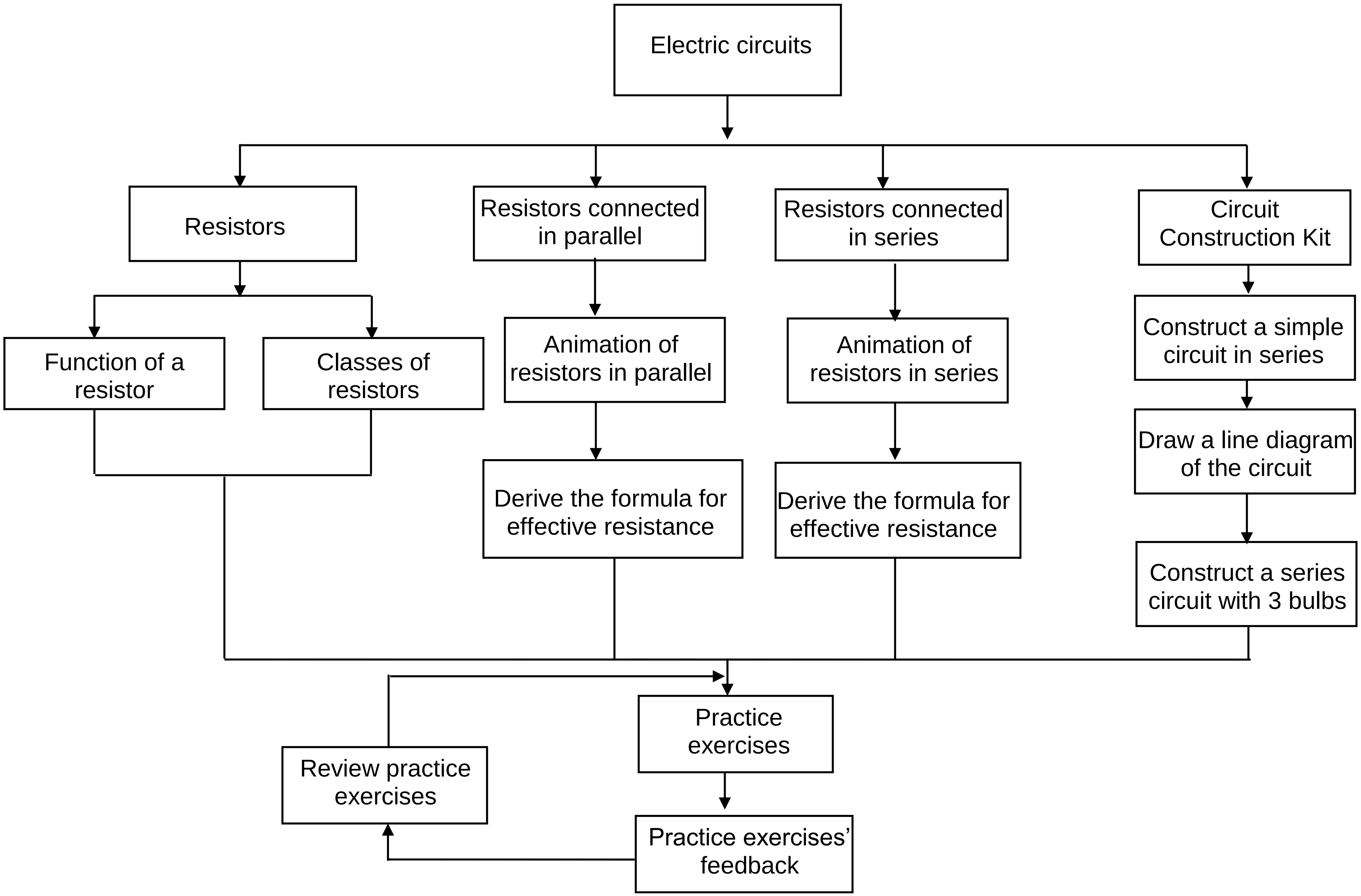

Figure 6: An arrangement of the units in the Electric Circuits' Tutorial

4.3 Development of the visuals for software prototype

The first stage of the development of the Electric Circuits' Tutorial (ECT) was to develop a paper mock-up of the structure and sequence of the tutorial in accordance with Mann (2005). This is referred to as the planning stage, which involves a detailed plan of the lesson on paper. The next stage was to conduct a task analysis and create flowcharts of the lesson. The detailed plan of the lesson was then translated into presentation slides using Microsoft PowerPoint. Mann (2005) referred to the paper mock-up as "a hand-drawn replica on paper". Figures 7, 8 and 9 represent hand-drawn mock-ups of the Electric Circuits' Tutorial (ECT).

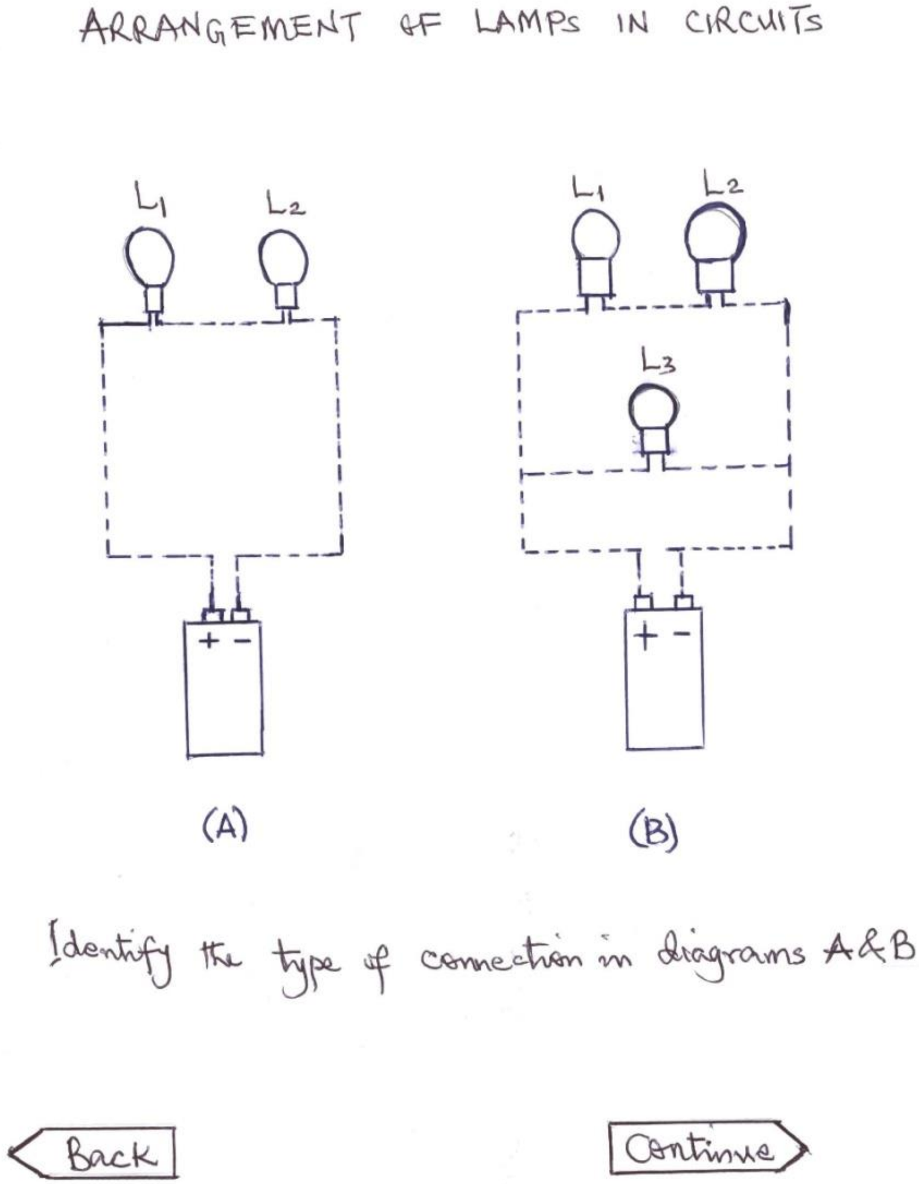

Figure 7. Hand-drawn replica of the Electric Circuits unit on arrangement of lamps in a circuit

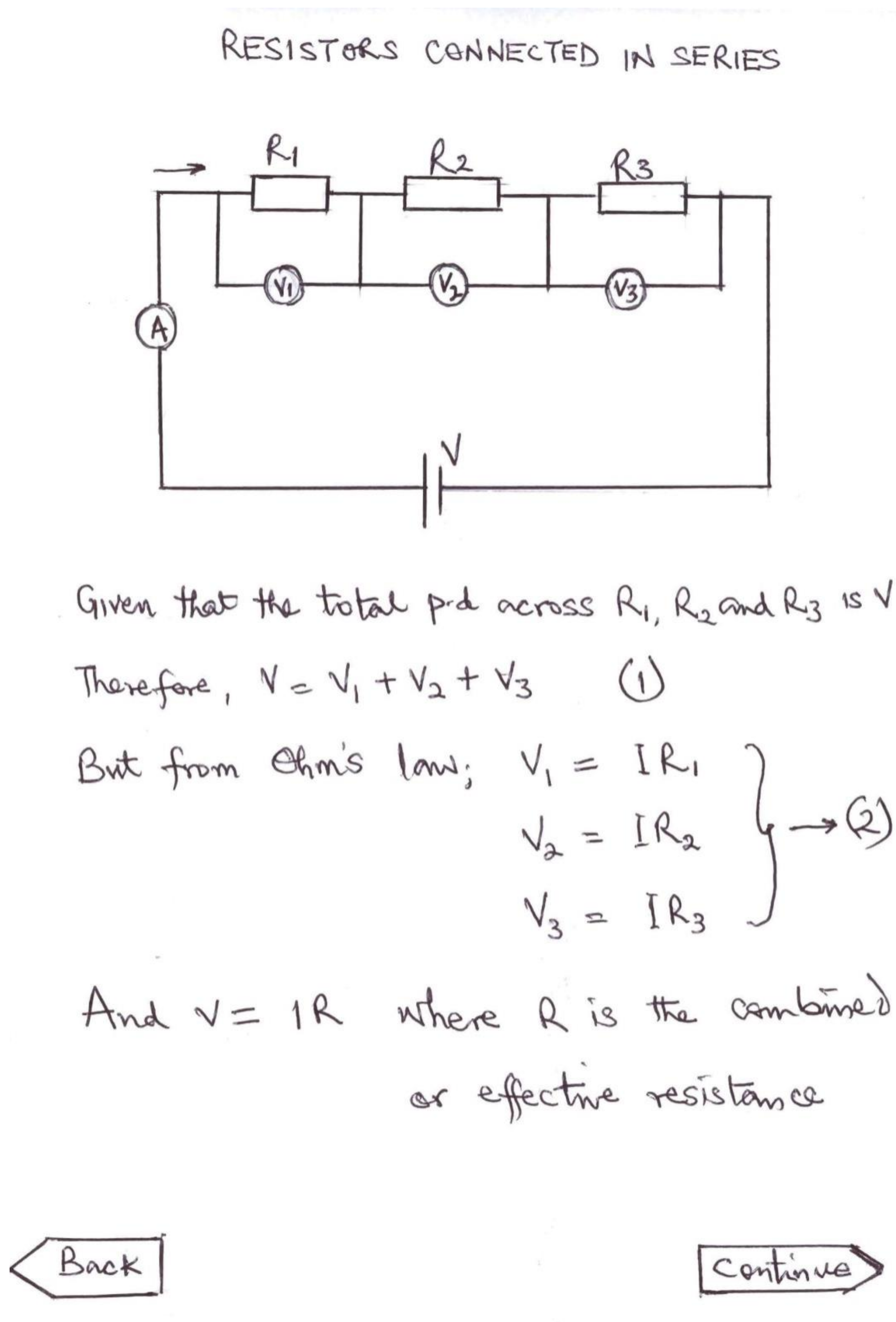

Figure 8. Hand-drawn replica of the Electric Circuits unit on resistors in series

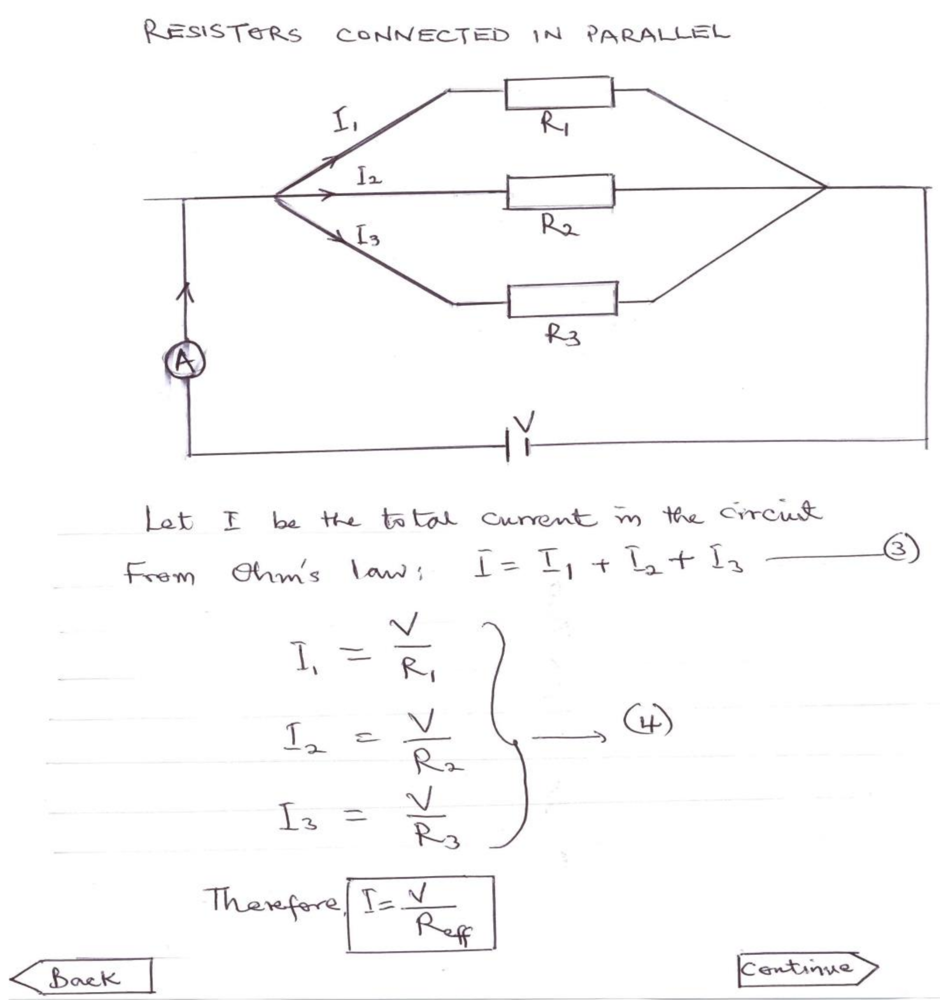

Figure 9. A replica of the Electric Circuits unit on resistors in parallel

The researcher also incorporated the Circuit Construction Kit (CCK) (PhET, 2015) in the ECT. The CCK is circuit construction simulation from a suite of computer simulations by the Physics Education Technology (PhET) (PhET, 2015) project, University of Colorado at Boulder, Boulder, Colorado, USA. The simulations have been used in similar studies and they have been adjudged as being valid and reliable. Finkelstein, Adams, Keller, Perkins, Wieman, and PhET Project Team (2006) used the PhET simulations in a research study entitled “Can computer simulations replace real laboratory equipment?” Their conclusion was that simulations can replace real lab equipment because the results of the research indicated that the students mastered the concepts better than real live and showed greater skills in assembling circuits after the simulations have been used.

The PhET simulations, ((PhET, 2015)) according to PhET are “animated, interactive, and in game-like environments where students are able to learn through exploration” (PhET, 2015). According to Perkins, Adams, Dubson, Finkelstein, Reid, Wieman and LeMaster (2006)

> in designing the simulations, emphasis is placed on the connections between real-life phenomena and the underlying science, and the simulations seek to make the visual and conceptual models of expert physicists accessible to students (p.1).

The Circuit Construction Kit (PhET, 2015) simulation was incorporated in the ECT so that the participants can use it to construct their own series and parallel circuits with the materials provided in the CCK. The screen capture of the Circuit Construction Kit (AC + DC) of PhET is shown in the figure below.

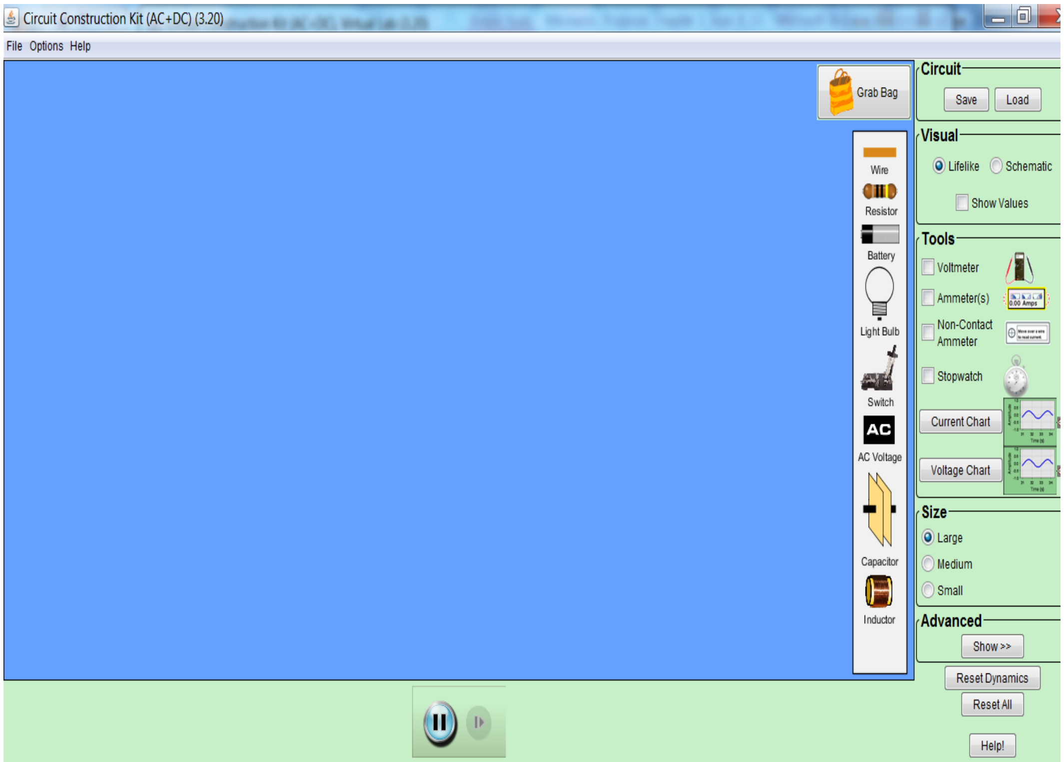

Figure 10. A screen capture of the Circuit Construction Kit by PhET (2013)

4.4 Development of the audio for software prototype

Temporal speech cues were used to apply audio to the visual events to affect students' knowledge of Electric Circuits. Temporal speech cueing is one of the six functions in the Structured Sound Function (SSF) model (Mann, 2006). The on-screen text version of the ECT has the bubble shown in the diagram below while the speech cueing version has the spoken sound. Figure 10 shows an example of the on-screen text of the Physics tutorial.

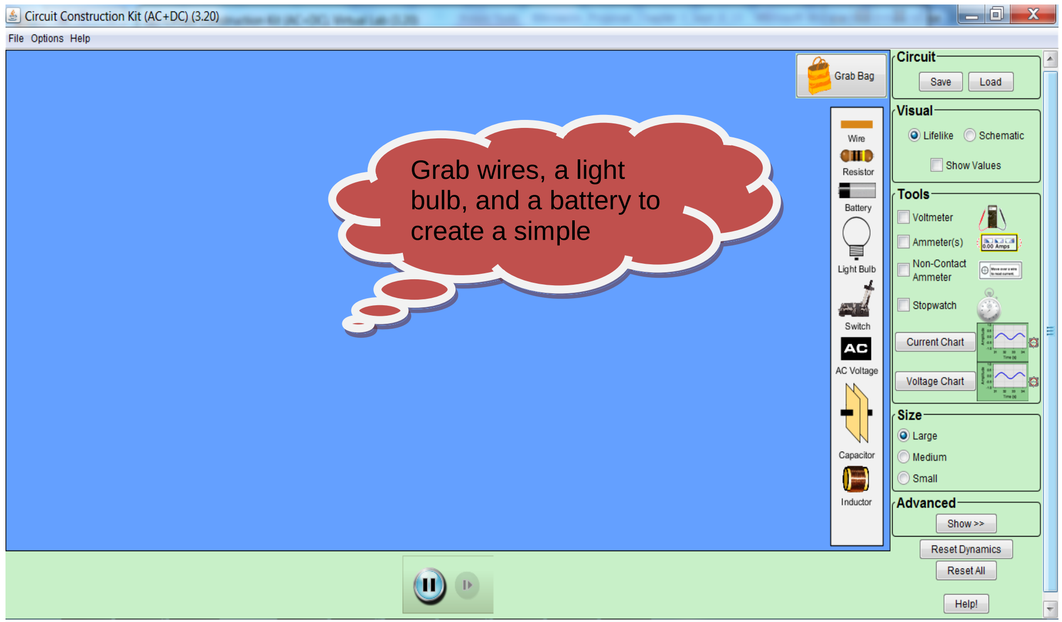

Figure 11. On-screen text giving instructions to the participant

The narrated screen text version of the ECT followed the method suggested by Mayer's (1997) cognitive theory of multimedia learning (CTML). The screen text was read out by a female voice consistent with research findings and in accordance with similar studies of this kind (Griggs, 2011; Atkinson, Mayer & Merrill, 2005; Higginbotham-Wheat, 1991, Mann, 1997b, 2002). The students were expected to select relevant words for verbal processing; select relevant images for visual processing; organize the words into a coherent verbal model and organize the images into a coherent visual model; and integrate corresponding components of the verbal and visual models (Mayer, 1997).

The following screenshots and accompanying transcripts illustrate the narrated text version of the ECT (a complete on-screen text version of the ECT can be found in Appendix K).

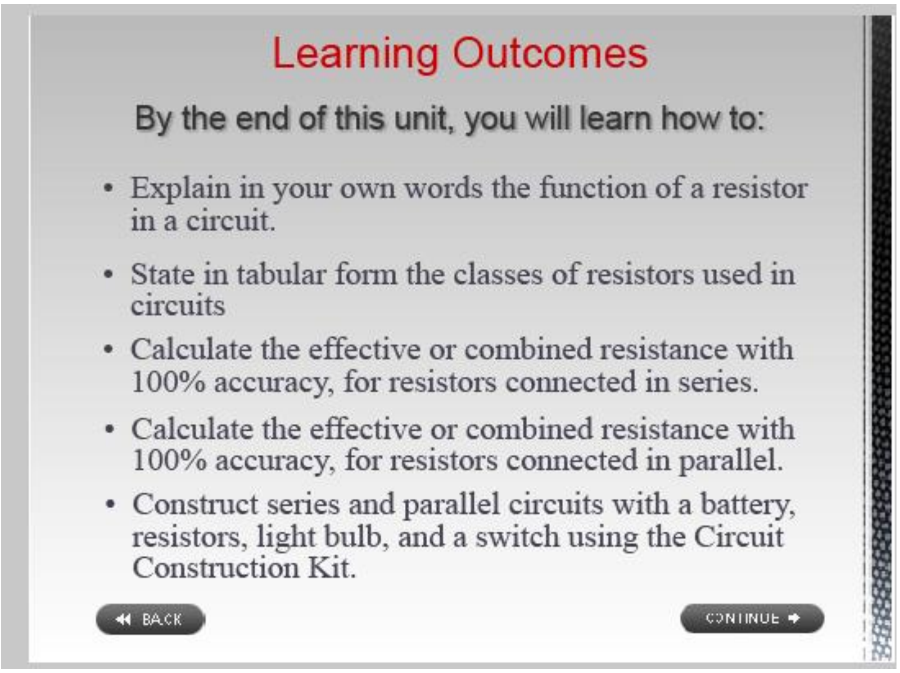

Figure 12. A screenshot of the learning outcomes

Audio transcript of figure 10 above: by the end of this tutorial…you will learn how to 1…. explain in your own words the function of a resistor in a circuit…..2…. State in tabular form the classes of resistors used in circuits……3… Calculate the effective or combined resistance with 100% accuracy, for resistors connected in series…..4… Calculate the effective or combined resistance with 100% accuracy, for resistors connected in parallel…..and 5… Construct series and parallel circuits with a battery, resistors, light bulb, and a switch using the Circuit Construction Kit.

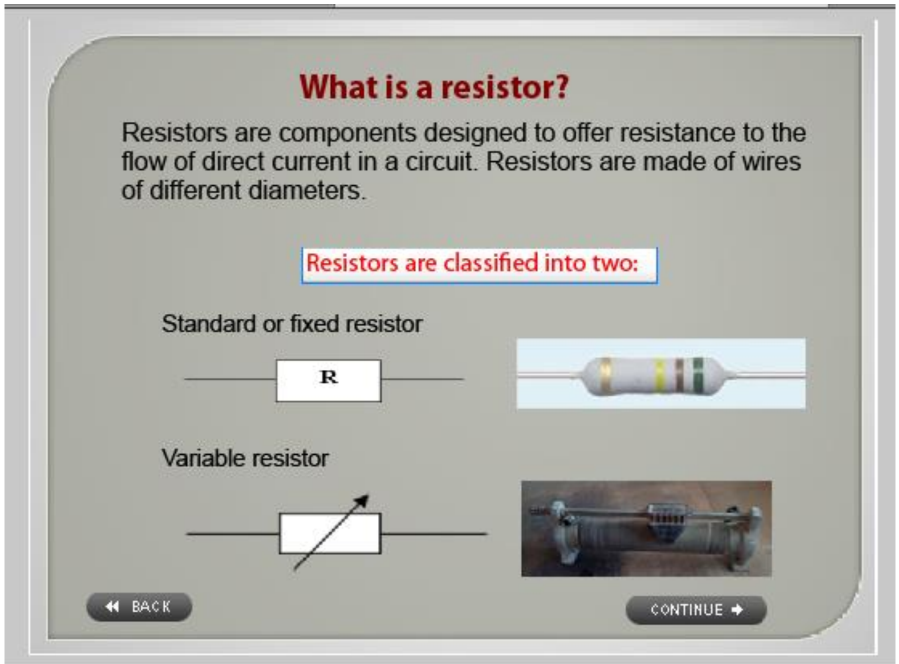

Figure 13. A screenshot of the slide "what is a resistor?"

The audio transcript of the narrated text version of figure 11 above: What is a resistor?...*pause*… Resistors are components designed to offer resistance to the flow of direct current in a circuit. Resistors are made of wires of different diameters.…*pause*… Resistors are classified into two…*pause*…standard or fixed resistor…*pause*…variable resistors.

The audio transcript of the equivalent convergent temporal speech cueing version is: "the diagrams show the image and electric symbols of a fixed resistor and a variable resistor…please take note of this".

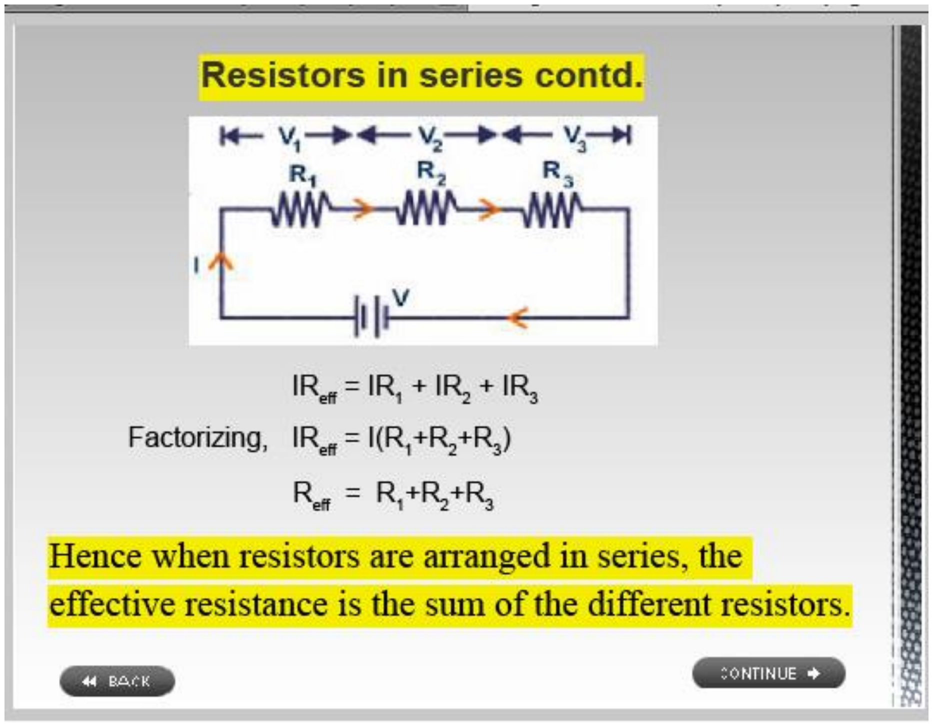

Figure 14. A screenshot of the slide "resistors in series contd."

The audio transcript of the narrated text version of figure 12 above: resistors in series continued….*pause*….the current multiplied by the effective resistance IR_{eff} is equals IR_1 plus IR_2 plus IR_3….factorising IR_{eff} is equal to I into bracket R_1 plus R_2 plus R_3 close bracket…..R_{eff} is equal to R_1 plus R_2 plus R_3.

Similarly, the audio transcript of the equivalent convergent temporal speech cueing version is "write down the formula in your workbook".

4.5 Summary

This chapter was dedicated to the design and development of the three version of the ECT – on-screen text, narrated text, and temporal speech cues. Each version of the ECT contained the same titles and contents. There were a total of 26 slides in the tutorial - 17 slides for the electric circuits content and 9 slides for the practice questions. The on-screen text version incorporated written text, graphics and animations. The narrated text version incorporated a learning environment with graphics and a balance of spoken and on-screen information. The temporal speech cues version of the ECT contained a brief spoken instruction, direction, hint, partial answer, reminder, or caution, in addition to the on-screen text. The three versions were formatively evaluated to improve their effectiveness.

The next chapter of this dissertation is a description of two of the stages of formative evaluation - the quality review and pilot test stages, of the three versions (convergent temporal speech cueing, narrated screen text, and on-screen text) of the tutorial on Electric Circuits for below-average Physics students in Ilorin senior secondary schools (SSS).

5. QUALITY REVIEW AND PILOT TEST

This chapter is a description of the quality review and pilot test of the three versions of the Electric Circuits' Tutorial (ECT) – narrated-text version, temporal speech cueing version, and the on-screen text version . *Stage one* of the formative evaluation is the quality review process of the three versions of the ECT by an instructional designer and four subject matter experts (SME's). One-to-one evaluation in Dick, Carey and Carey's (2014) model also formed part of the quality review. *Stage two* is a pilot test of the tutorials consistent with Alessi and Trollip's (2000) and Dick, Carey and Carey's (2014) formative evaluation models. *Stage three* is the validation of the three versions of the ECT designed for depth of learning, in keeping with previous studies on cueing (Mann, 2006). This chapter is also an analysis of the results of the quality review and pilot test.

5.1 Chronology of the Research

Table 6 below is an illustration of the chronology of the research. Items 1-5 in the chronology have been completed prior to the formative evaluation (items 6-9) of the Electric Circuits' Tutorial (ECT). These items enabled the researcher to stay on track and were completed according to the plan of the research.

Table 6

Chronology of the research

No.	Stage	Duration	Resources
1	Research problem identified in previous research	6 months	Library
2	The local need assessed	3 weeks	SME, ID'er, paper forms, Web forms
3	Instructional design of the tutorials using MS-PowerPoint	5 weeks	Screen capture software, etc
4	Captivate eLearning tutorial development	200 hours	Adobe Captivate eLearning tool/user manual and videos
5	Modifications	25 hours	Informal feedback from colleagues
6.	Stage 1: Quality review	2 weeks	ID, SME's and twelve students
7.	Stage 2: Pilot study	2 weeks	Twelve (12) students
8	Stage 3: Validation / experiment	6 weeks	36 students
9	Delayed posttest	6 weeks after the experiment/validation	36 students

The above chronology of research was adopted to guide the design of the research and the formative evaluation of the tutorials for below-average Physics students. The chronology was adopted to enable the researcher to remain focused and directed on the path of the research. The next section is a description of the three-stage formative evaluation of the Electric Circuits Tutorial (ECT) according to the models in Alessi and Trollip (2000) and Dick, Carey and Carey (2014).

5.2 Stage 1: The Quality Review

Three sets of reviewers were involved in the quality review stage: The first set was made up of 12 participants from the 4 schools (one-to-one evaluation); the second set was made up of 4 subject matter experts (physics teachers), one from each of the selected schools; and the third was an instructional designer. The purpose of a quality review is to eliminate correctable errors (Mann, 2006). The procedure for the quality review was:

1. Select 12 participants for one-to-one, four physics teachers, and one instructional designer. Brief biographies of each are presented in sub-sections 5.2.2 and 5.2.3
2. Explain the procedure to them (that is, sequential training and training on verbal protocols)
3. They evaluate the tutorials
4. They record their observations in the evaluation forms in Appendices E, F, and G.

The feedback received from the one-to-one evaluation, the Subject Matter Experts, and the Instructional Designer during this stage provided the recommendations for revision to the prototype and documentation. In the Quality Review stage, the following questions as proposed by Smith and Ragan (1999) were answered.

1. How well do the practice questions and their related mastery criteria reliably distinguish between competent and incompetent learners? “Competent learners” is operationalized as obtaining a 50% score in the posttest. “Incompetent learners” is operationalized as obtaining below 50% in the posttest.
2. What are the areas of the self-instructional units that need to be revised?
3. How well are the instructional strategies consistent with principles of instructional theory, as defined by Merrill (2002)?
4. Does the task analysis include all the prerequisite skills and knowledge needed to perform the learning goal?
5. Are the prerequisite nature of the skills and knowledge accurately represented?

The profile of the sample that was involved in the quality review stage of the formative evaluation (internal reviews) was as follows:

5.2.1 One-to-one evaluation

The one-to-one evaluation with learners was the first part in the quality review stage. Three students in grade 11 (Senior Secondary School 2) Physics class from each of the four selected schools, corresponding to a total of twelve students, served as evaluators in this regard. This represented four students for each version (temporal speech cueing, narrated screen text, and on-screen text groups) of the ECT. This was done to increase the feedback and response from the participants. The participants were required to self-explain as they used the tutorial by following the procedure in the tutorial while the researcher and/or research assistant probed and reminded the participants to continue to self-explain during the process. The participants were expected to attempt the pre-test, follow the procedure in the lesson and the electric circuits content covered, attempt the practice questions and finally attempt the post-test. The participant's overall impression and review was recorded in the student questionnaire in the appendix G.

5.2.2 Four Subject Matter Experts Reviews

The subject matter expert review is the second part of the quality review stage of the formative evaluation. Four Physics Teachers, one from each of the selected schools, were recruited to participate in the internal review of the tutorial as the Subject Matter Experts (SME's). The teachers' consent to participate in the research was sought because they were responsible for teaching Physics to the grade 11 students who participated in the research. The teachers had taught Physics for several years (5-10 years) therefore their subject matter knowledge in electric circuits may be regarded as reasonably adequate, that is, they were familiar with electric circuits. One of the teachers was a graduate with a Bachelor's degree in electrical engineering and a postgraduate diploma in education. The other three teachers had Bachelor of education degrees in physics. The SME's overall impression and review of the Electric Circuits Tutorial was recorded in the questionnaire in Appendix E of this dissertation.

5.2.3 Instructional Designer Review

A former colleague who had taught Physics in high schools in Ilorin, Nigeria for over 10 years and also designed instructional materials for teaching Physics and Chemistry served as the Instructional Design expert for this research. The Instructional Designer had a Bachelor's degree in Science Education and a Master's degree in Educational Technology. The Instructional Designer's overall impression and review of the electric circuits' tutorial was recorded in the questionnaire in Appendix F of this dissertation. An exemplary quality review according to Alessi and Trollip (1991) includes:

the language & grammar, the displays and surface features, the purposeful use of audio, the questions and menus, and the subject matter

5.3 Results of the quality review

This section is a presentation and analysis of the results of the quality review stage. The outcome of the quality review indicated that some areas of the tutorial need review. All the formative evaluation questions were derived from Smith and Ragan (1999).

Question 1: How well do the practice questions and their related mastery criteria reliably distinguish between competent and incompetent learners? "Competent learners" is operationalized as obtaining a 50% score in the posttest. "Incompetent learners" is operationalized as obtaining below 50% in the posttest.

The participants in the one-to-one evaluation reported that the practice questions provided were relevant to the materials learned and the questions provided them with the opportunities to review what was learned. The participants also reported that the practice questions were clearly stated (11 out of the 12 participants corresponding to about 92% asserted to this). Furthermore, the subject matter experts (SMEs) agreed that the questions and exercises represented a reliable tool to distinguish between competent and incompetent learners. Table 7 below indicates the responses from the SMEs concerning the practice questions. In the Likert scale, SA represents Strongly agree; A represents Agree; N represents Not sure; D represents Disagree; and SD represents Strongly disagree.

Table 7

'Questions and responses' from the questionnaire for SMEs

	SA	A	N	D	SD
The practice exercises were easy to follow and complete at the end of each module.	1	3	Nil	Nil	Nil
The practice exercises were relevant to the pretest.	1	3	Nil	Nil	Nil
The exercises were related to the objectives.	2	2	Nil	Nil	Nil
The length and frequency of the exercises was appropriate.	Nil	3	1	Nil	Nil
The difficulty of the exercises was appropriate.	1	3	Nil	Nil	Nil
The types of exercises were appropriate.	1	3	Nil	Nil	Nil

Question 2: What are the areas of the self-instructional units that need to be revised (Smith & Ragan, 1999)?

The participants in the quality review indicated that the Electric Circuits' Tutorial (ECT) adequately captured the topic and provided an in-depth discussion of the qualitative and the quantitative aspects of electric circuits. For example, one of the participants in the temporal speech cues group wrote in her comment "the review is actually nice and understandable".

However, revisions were required in certain areas of the ECT. One of the areas that the participants indicated that required revisions was in the use of formulae. Two of the participants in the on-screen version of the ECT noted that the formulae used to determine the effective resistance of resistors connected in series and for resistors connected in parallel were not clear to them. Furthermore, the participants observed that the PhET Circuit Construction Kit (CCK) was not adequately integrated within the ECT. They suggested that the CCK should include some clear directions on what to do. For example, a participant pointed out in her comment “I was not able to construct the circuit using the CCK”. Furthermore, the instructional designer suggested that there should be more opportunities for interaction with the ECT, consistent with the definition of interactivity in multimedia learning (Domagk, Schwartz & Plass, 2010). “Interactivity in the context of computer-based multimedia learning is a reciprocal activity between a learner and a multimedia learning system, in which the [re]action of the learner is dependent upon the [re]action of the system and vice versa” (Domagk, Schwartz & Plass, 2010, p. 1025).

During the quality review, the researcher and research assistant carried out troubleshooting and found out that the absence of Java software on the computer machines prevented the PhET CCK from running. Therefore, Java software was installed on the computer machines prior to the pilot test stage of the formative evaluation.

Question 3: How well are the instructional strategies consistent with principles of instructional design theory, as defined by Merrill (2002)?

The instructional strategies referred to here are those concerned with the design of the ECT. Merrill (2002) identified five principles of instructional design theories, which are:

(a) Learning is promoted when learners are engaged in solving real-world problems.

(b) Learning is promoted when existing knowledge is activated as a foundation for new knowledge.

(c) Learning is promoted when new knowledge is demonstrated to the learner.

(d) Learning is promoted when new knowledge is applied by the learner.

(e) Learning is promoted when new knowledge is integrated into the learner's world.

The formative evaluation examined how well the instructional strategies incorporated those five principles of instructional design theories. Analysis of the responses in the SME's evaluation form shows that the instructional strategies adopted in the ECT were consistent with Merrill's (2002) principles of instructional design. For example, a section of the tutorial titled "check your prior knowledge" was used to activate participants' prior knowledge. All the four (4) SMEs agreed that the prerequisite nature of the skills and knowledge were accurately represented. However, one of the SMEs noted that "the presentation does not use what can be easily seen in the environment. For example, current can be presented as a flow of water through a pipe. In this case, the pipe is the resistance”.

Responses of the participants in the one-to-one evaluation also show that the content of the ECT was structured in a logical manner with relevant practice and learning activities provided. One of the participants stated that he found the sound in the ECT interesting.

Question 4: Does the instructional analysis include all the prerequisite skills and knowledge needed to perform the learning goal?

The analysis of the responses from the SMEs shows that the task analysis included a reasonable number of prerequisite skills and knowledge needed to perform the learning outcomes. For example, the Instructional Designer (ID) indicated that the leading questions provided a means of checking students’ prior knowledge. However, the ID suggested that more challenging questions should be included in the practice exercises because some of the practice questions were lower-order questions. One of the SMEs also noted that “the questions are moderately simple. This is a plus. Efforts need to be made to widen the question bank to accommodate students of various abilities”.

The suggestions on increasing the number of practice questions and making them more challenging have been noted for further review to the ECT. The recommendation has been recorded in the “recommendations for revision” section in this dissertation.

Question 5: Are the prerequisite nature of the skills and knowledge accurately represented?

Analysis of responses of the ID and SMEs showed that the prerequisite skills and knowledge were well represented in the ECT. The responses to the questionnaire items on *prerequisite nature of the skills and knowledge of electric circuits* showed that all the four SMEs agreed that the ECT contained examples and instances to help learners understand the module. Additionally, the participants involved in the one-to-one internal review indicated that the skills they acquired in the ECT helped them to answer the practice questions.

Merrill (2002) noted that learning is promoted when existing knowledge is activated as a foundation for new knowledge, therefore the reviewers found the aspects of the ECT that attempted to activate the prior knowledge of the participants useful. Although some of the reviewers in the one-to-one evaluation noted that they have forgotten the answers to those questions under “activate your prior knowledge” because they learned the topic while they were in grade 10 (that is, the previous academic year).

Other features of an exemplary quality review

Some other areas of an exemplary quality review include (Alessi & Trollip, 2000), which the instructional designer (ID) responded to:

- The language & grammar is correct and free from errors, the language is appropriate and easy to follow. Furthermore, the ID agreed that the content was presented in a language appropriate for the learners.
- The displays and surface features were considered adequate by the ID.
- The questions and menus: The instructional designer suggested that more challenging questions should be included to cater to students with varying abilities.
- The subject matter was considered accurate and appropriate to the students' level by the Instructional Designer.

Revisions were made to the tutorial following the quality review with the students (one-to-one evaluation), the subject matter experts, and the instructional designer. The researcher and research assistant observed during the quality review stage that the students were spending longer time (more than one hour) in completing the ECT. Therefore, further review was done to cut down on the practice questions. Particularly, practice questions 5 and 6 shown below were removed because the students were spending too long in solving the problems and they were not getting the right answer. This may be as a result of the difficulty level of the practice questions.

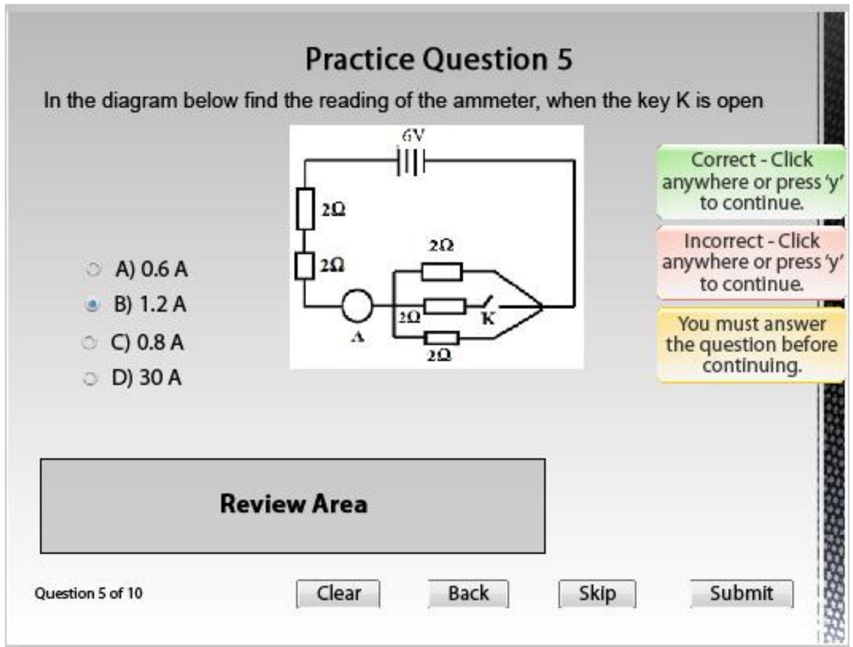

Figure 15. Practice question 5 from the ECT

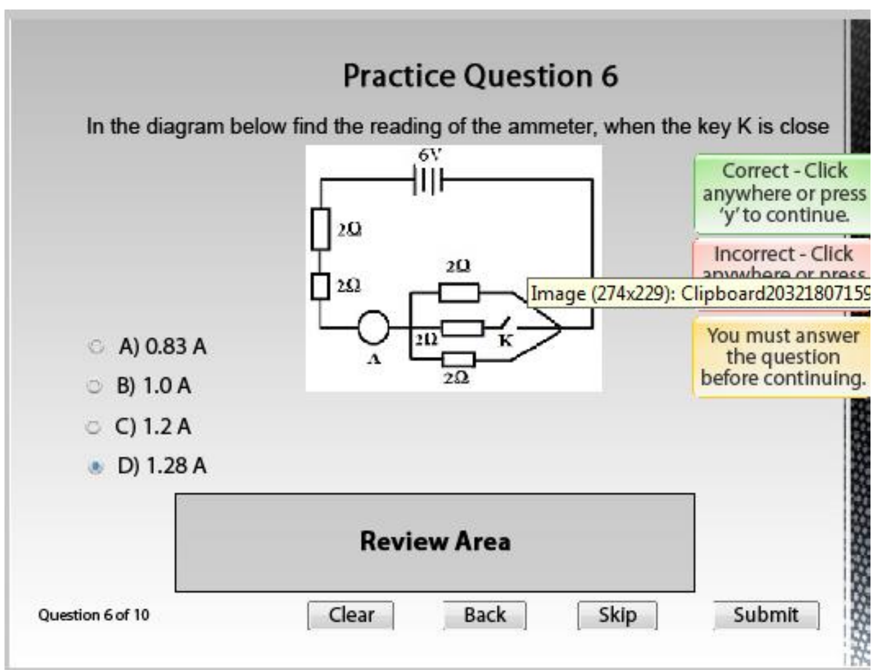

Figure 16. Practice question 6 from the ECT

Moreover, the learning outcome, which involved students constructing parallel electric circuits with a battery, light bulbs, and a switch using the Circuit Construction Kit was removed in order to reduce the duration of the ECT. The wording of the learning outcomes was rephrased to follow the ABCD format of writing objectives for clarity and measurability (Mann, 2005). The ABCD format as described by Mann (2005) recommended that learning outcomes should be stated to include the A (audience), the B (behavior), the C (condition), and the D (degree). For example, as described in page 66 in this dissertation, one of the objectives was rephrased to read "at the end of the unit (condition), the students (audience) should be able to calculate the effective or combined resistance (behaviour) with 100% accuracy (degree), for resistors connected in series". Also slide 14 was revised, as observed by the instructional designer, to reflect that when determining the effective resistance of resistors connected in parallel, instead of "sum of resistance" it should read "sum of products of resistance". The formula before revision was as shown below:

$$R = \frac{R_1 R_2 R_3}{R_2 R_3 + R_1 R_3 + R_1 R_2} = \frac{\text{product of resistance}}{\text{sum of resistance}}$$

The formula was changed to read:

$$R = \frac{R_1 R_2 R_3}{R_2 R_3 + R_1 R_3 + R_1 R_2} = \frac{\text{product of resistance}}{\text{sum of products of resistance}}$$

Based on the observations made by the participants and reviewers, playback control was also incorporated to enable easy navigation. The timing of the controls was adjusted to sync with the slides thereby saving time spent waiting for the controls to load.

5.4 Stage 2: The Pilot Test

The pilot test is the second stage in formative evaluation. The purpose of a pilot test is to debug the software prototype and documentation, and correct any obvious problems (Mann, 2006). Moreover, Dick, Carey and Carey (2004) identified two primary purposes of the pilot test stage: “the first is to determine the effectiveness of changes made following the quality review and the second is to determine whether the learners can use the instruction without interacting with the instructor” (p. 288). The pilot test stage corresponds to the small-group try-outs stage of a formative evaluation in the Dick, Carey and Carey’s (2004) model. The pilot test of the ECT was carried out with three (3) participants from each of the selected schools (a total of 12 participants, representing 4 participants for each version of the ECT) using the 7-step procedure below (Alessi and Trollip, 2000):

1. Select a participant
2. Explain the procedure of the research to him/her (training on the software and verbal protocols)
3. Determine their prior knowledge using the pretest
4. Observe him/her using the program

5. Interview him/her afterwards
6. Assess their learning using the posttest
7. Take notes on how the tutorial could be revised

Dick, Carey and Carey (2004) identified two typical measures used to evaluate instructional effectiveness as learners' scores on a pretest and a posttest, as well as an attitude questionnaire. In the Pilot Test stage, the following questions were answered in accordance with the recommendation of Smith and Ragan (1999):

1. To what extent were the participants able to interpret the text and graphics in the self-instructional units?
2. How well do the participants understand the instruction?
3. Do the participants know what to do during the practice and tests?
4. To what extent do the participants demonstrate the anticipated entry-levels skills that will make them succeed in the instruction?
5. How long does it take for the participants to complete the instruction?

5.5 Results of the pilot test

This section is a presentation and analysis of the results of the pilot test. The outcome of the quality review indicated that some areas of the tutorial need review. The following questions guided the quality review stage:

Question 1: To what extent were the participants able to interpret the text and graphics in the self-instructional units?

In order to determine the extent to which participants were able to interpret the text and graphics in the ECT, feedback received from the participants in the pilot test, scores in the practice exercises, and the researcher/research assistants' observation notes were analysed. The various comments by the students indicate that they were able to interpret the text and graphics and they found them useful. For example, a participant commented that "the reading material opened my brain more on things of physics especially in cells, resistance and voltage". Another participant further indicated how she was able to understand the text and graphics by commenting that "the graphics, colour coding, were good. I liked it because I am normally attracted to colours". Furthermore, analysis of the participants' scores in the practice exercises gave an indication of the extent to which they were able to integrate the texts and graphics in the ECT. Nine participants, four in the convergent temporal speech cueing group, four in the narrated screen text group, and one in the on-screen text group during the pilot test scored above 50% in the practice exercise while the remaining three of the participants in the on-screen text group scored below 50%.

Furthermore, the researcher and research assistants observed that the participants were engrossed and wholly involved with the ECT in an attempt to complete the unit in the least time possible. The researcher had to remind the participants that the ECT is a tutorial that allows 'you to learn at your own pace'.

They were also reminded that they may pause or play back if they need more time to understand a concept. The participants were seen making notes, listening to instructions, and interacting with the ECT.

Question 2: How well do the participants understand the instruction?

The operational definition of “understanding the instruction” is the results of the pretest and the posttest of the participants in the pilot test. This is consistent with the suggestion of Dick, Carey and Carey (2004) that two typical measures used to evaluate instructional effectiveness are the learners’ scores on a pretest and a posttest. Analysis of the results obtained at the end of the ECT practice questions and the scores in the pretest and the post test showed that the participants achieved a score of 50% in the practice tests. The general performance in the posttest was a little above 50%, however, it is important to indicate that the participants in the convergent temporal speech cueing group and the narrated screen text group made significant gains in the posttest. Furthermore, few clarifications on what to do in the practice questions and the posttest were made to the participants during the pilot test.

Furthermore, analysis of the notes taken by the participants during the pilot test suggests that they understood how to progress through the ECT. The participants in the three groups took notes and made sketches of the circuits in the ECT before attempting to solve the problems. The participants may have been impressed with their notes because they asked the researcher if they could retain the notes for future reference. However, the researcher had to point out to the participants that the notes were parts of the data for the research and therefore would need to be analysed.

Question 3: Do the participants know what to do during the practice and tests?

The operational definition of "knowing during practice and tests" is the ability of the participants to progress through the practice questions while self-explaining and to answer the posttest with minimal clarifications from the researcher/research assistants. The observation of the researcher and research assistants showed that most of the participants (9 out of 12) in the three versions of the ECT knew what to do during the practice questions. However, occasionally some participants (2 of the participants in the on-screen text version) did not know how to proceed after answering one question. They 'forgot' to click the submit button in order to proceed to the next question.

In the pilot test, there was a gain in the performance of the participants from the pretest to the post test. Participants in the narrated screen text group achieved a mean gain of 91.5%, the on-screen text group achieved a mean gain of 0%, while the participants in the convergent temporal speech cueing group achieved a mean gain of 61.2%.

Question 4: To what extent do the participants demonstrate the anticipated entry-levels skills that will make them succeed in the instruction?

The ECT included some leading questions designed to check prerequisite skills. The questions were presented before the materials to determine if the participants possess the requisite skills. Dick, Carey and Carey (2004) observed that activities intended to inform learners of prerequisite skills required to begin an instruction are very important components of developing an instructional strategy.

Analysis of the notes taken by the participants in the pilot test revealed that they did not demonstrate the anticipated entry level skills correctly. The researcher observed that the participants spent some time thinking about the leading questions. The researcher and research assistants had to instruct the participants to proceed with the tutorial instead of spending too much time on the leading questions. The participants could not answer correctly the leading questions and the items intended to check their prior skills contained in the Electric Circuits' Tutorial.

However, the aspect that checks the entry level skills of the participants was not removed from the ECT after the pilot test because the researcher intended to ascertain if it was only the participants in the pilot test or all the other research participants that would have difficulty with those entry level items. It turned out that the participants in the experiment/validation stage experienced similar difficulties with the items that were designed to check the entry-level skills of the participants. The reason the participants gave for their inability to answer the leading questions was that they had forgotten the electric circuits they were taught in their previous year (grade 10).

Question 5: How long does it take the participants to complete the instruction?

The time duration was measured by the counter on the computer sound recorder. Analysis of the audio recordings of the 12 participants in the pilot test shows that the participants in the on-screen text version spent less time (approximately 1 hour) on the ECT than the participants in the other two groups (narrated screen text group and convergent temporal speech cueing group). The observation notes of the researcher during the pilot test revealed that the participants in the narrated screen text group and the convergent temporal speech cueing group spent more time on the ECT because of the attention they paid to the sound cues or the time they spent listening to the narration.

5.6 Recommendation for revisions

This section is a description of the recommendations for revisions that were made, but could not be implemented in the ECT before the validation/experiment stage. The ECT was revised as mentioned on page 91 in this dissertation. However, some recommended revisions could not be implemented because of time limitations and technical constraints. For example, the Circuit Construction Kit (CCK) could not integrate adequately with the Adobe Captivate software used to design the ECT; therefore, the CCK was opened independently from the ECT. That is, the CCK was launched from the start menu in Windows. Some of the participants reported that they did not know what to do and how to proceed as a result of this inability to launch the CCK from within the ECT. It was recommended that more compatible e-learning software with the CCK be used for future design. Another recommendation was that practical examples that relate to the learners immediate environment should be used in the tutorial. This recommendation could not be implemented in the tutorial revision because of time constraint.

5.7 Summary

Chapter five was devoted to the design and formative evaluation of the temporal speech cueing, narrated screen text, and on-screen text versions of the ECT used in the research. The purpose of the formative evaluation was to improve the quality of the ECT and to increase the effectiveness of the ECT. The procedure of the three-stage formative evaluation of the three versions of the electric circuits' tutorials was described. The results of the quality review and pilot test enabled the researcher the review the ECT and correct any avoidable errors. There were some suggestions/recommendations that could not be incorporated because of time and equipment constraints. Those recommendations were noted and are expected to form part of the researcher's future research. Chapter five was also a description of the questions that guided the formative evaluation of the tutorials. Five questions guided the quality review and five questions guided the pilot test.

The formative evaluation of three units of instruction in the Electric Circuits Tutorial (ECT) allowed the designer to discover and fix any errors before implementation in the main research. Details of the revisions made to the ECT were discussed in page 91 of this dissertation. The formative evaluation process which was adopted has three stages as suggested in most models (Dick, Carey & Carey, 2009; Alessi & Trollip, 2001). Recapping, *Stage 1* was the quality reviews by an Instructional Designer, 12 students, and four Subject Matter Experts. *Stage 2* was a pilot test of the instructional prototype with 12 students, four for each version of the Electric Circuits tutorial. *Stage 3* was a field test or validation of the tutorial.

The next chapter will be a description of the validation stage; which is the third stage of the 3-stage formative evaluation (Alessi, & Trollip, 2001). A separate chapter was created for the validation and experiment to ensure clarity and for better organization of the dissertation. The validation stage corresponded with the experiment in this research. The next chapter will describe the verbal protocols used for collecting data as the participants engage with the ECT.

6. FIELD TRIAL: VALIDATION AND EXPERIMENT

Chapter six of this doctoral dissertation is a description of the field trial which served a dual purpose - the validation of the Electric Circuits Tutorials (ECT) and the experimental comparison of the three versions of the ECT for below-average senior secondary school Physics students with fifty-one participants (forty-five participants dropped out from the remaining ninety-six). Validation is the third stage in the formative evaluation process (Alessi & Trollip, 2001). Stage one (quality review) and stage two (pilot test) were discussed in chapter five. During the experiment, which examined the learning process, participants were involved in self-explanations as they used the ECT and the PhET Circuit Construction Kit (CCK) interactive simulation. This chapter is also a description of the method adopted for analyzing the data and the results.

6.1 Stage 3: Validation

The purpose of the validation stage was to ascertain “whether the program meets its goals in the real learning environment” (Alessi & Trollip, 2001, p. 553). The validation involved capturing participants’ self-explanations as they worked through the ECT and the PhET Circuit Construction Kit (CCK) interactive simulation in the “explorer centre”, consistent with the method in Mann (1996). For an explanation of explorer centre see figure 5 on page 61. The design of the validation was a comparison of three equivalent groups with different versions of the Electric Circuits’ Tutorial. The independent variables were the modality and instructional methods used and the dependent variables were the participants' attentional focus operationalized as more quality self-explanations about a concept, principle or problem solution and the participants' performance in the posttest (both the immediate and delayed). The design of the validation is illustrated in table 8 below:

Table 8

Design of the Validation and experiment

Independent variables		Dependent variables
Attribute/modality	Instructional methods	Attentional focus & Outcomes (posttest and delayed posttest)
Structured Sound Function (sound & graphics)	Convergent temporal speech cue	Better attentional focus measured by more quality self-explanations
Modality effect (graphics + narration)	Narrated screen text	Reduced attention focus operationalized as less quality self-explanations
Modality effect (on-screen text & graphics)	On-screen text	Reduced attention focus operationalized as less quality self-explanations

6.1.1 Procedures of the validation stage

The procedure in the validation stage followed that suggested in previous studies of this kind (Brown & Mann, 2001; Mann, et al., 2002). The sequential training lasted for three days, training on verbal protocol lasted for four days (two hours for each school per day) and the validation/experiment lasted just approximately ninety (90) minutes for each participant. The figure below captures the procedures of the validation stage.

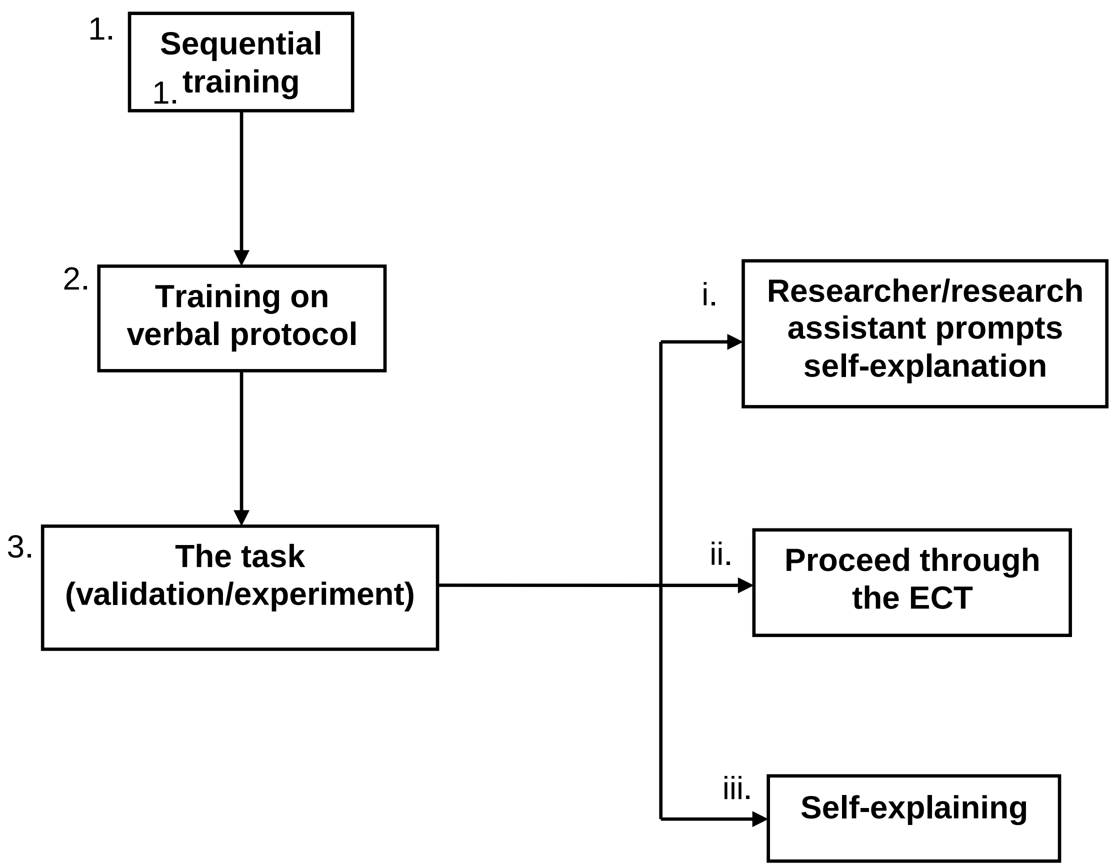

Figure 17: Procedure for the validation/experiment

Step 1: Sequential Training

Two research assistants were recruited - one graduate student of science education at the University of Ilorin and the other was a graduate student in the faculty of arts, University of Ilorin. These two research assistants were recruited to provide assistance with several research-related activities such as recruitment of participants, administration of instruments, prompting participants to self-explain during the validation and experiment stage, and other duties as assigned by the researcher. The researcher trained the research assistants first. Training on the software was then provided by the researcher and research assistants. Three versions of the Electric Circuits tutorial were developed: convergent temporal speech cueing, narrated screen text, and on-screen text version. The three tutorials contained the same title to orient the student.

Step 2: Training on Verbal Protocols

Participants were told that the researcher was interested in how they proceed through the ECT and how they arrive at their answers to the practice questions; another version of tutorial was used for this process. Participants were then presented with the program and asked to describe aloud what they were thinking, doing, attending to, or planning in the course of learning from the ECT and solving a problem.

The researcher then modelled the task with the practice program while thinking aloud. Participants were then asked to practice the protocol and task using the practice program. During this practice, the researcher and/or research assistants interacted freely with the participants, offering suggestions and encouraging them to verbalize their thinking. When both the participant and the researcher were satisfied with the participant's use of the protocol, the validation then proceeded to the next step, which was the experiment and consisted of self-explanation protocols as the participants progressed through the ECT.

Step 3: The Task

Participants were required to proceed through the tutorial on “Electric Circuits” by following the instructions and self-explaining. The ECT was expected to last for approximately one hour. The verbalizations were audio and video recorded and transcribed along with the researcher's notes about relevant nonverbal behaviors. Participants were instructed to self-explain what they were thinking, doing, attending to, or planning in the course of learning from the ECT and while constructing their circuits with the CCK from PhET. Each self-explaining session was initiated by the request from the researcher, "as you go through the program, just keep explaining how you are getting your answers." When a participant "froze", the researcher asked one of the following questions to generate a verbal response: (a) What are you trying to do now?; (b) What is holding you up?; or (c) Why are you quiet? Following the self-explanation, an informal discussion was conducted to debrief the students of any personal strategies they used. It was anticipated that their verbal reports will concentrate primarily on information concerning their immediate attention, that is, how they focused their attention while learning from the ECT. In this informal discussion, which was not recorded, participants were encouraged to recall their own procedures for learning "Electric circuits".

6.2 Results of the validation and experiment

Verbal data analysis was adopted as the method of data analysis. Verbal data analysis (Chi, 1997) is a type of analysis that integrates both qualitative and quantitative components of analysis. That is, it is a type of analysis that quantifies qualitative codings. Written transcripts of the participants' audiotapes were used while reviewing the audiotapes to aid in the segmentation procedure as described here. Three broad segmentation guidelines were implemented. First, the verbal transcript was divided at each new thought. Second, grammatical cues (such as therefore, because) that combine one or more ideas and verbs indicated a separate sentence. Third, pauses and reflective utterances such as 'un' or 'ah' were interpreted as indications that participants were moving into a new thought. There were three types of coding of the verbal data as shown in figure 18 below.

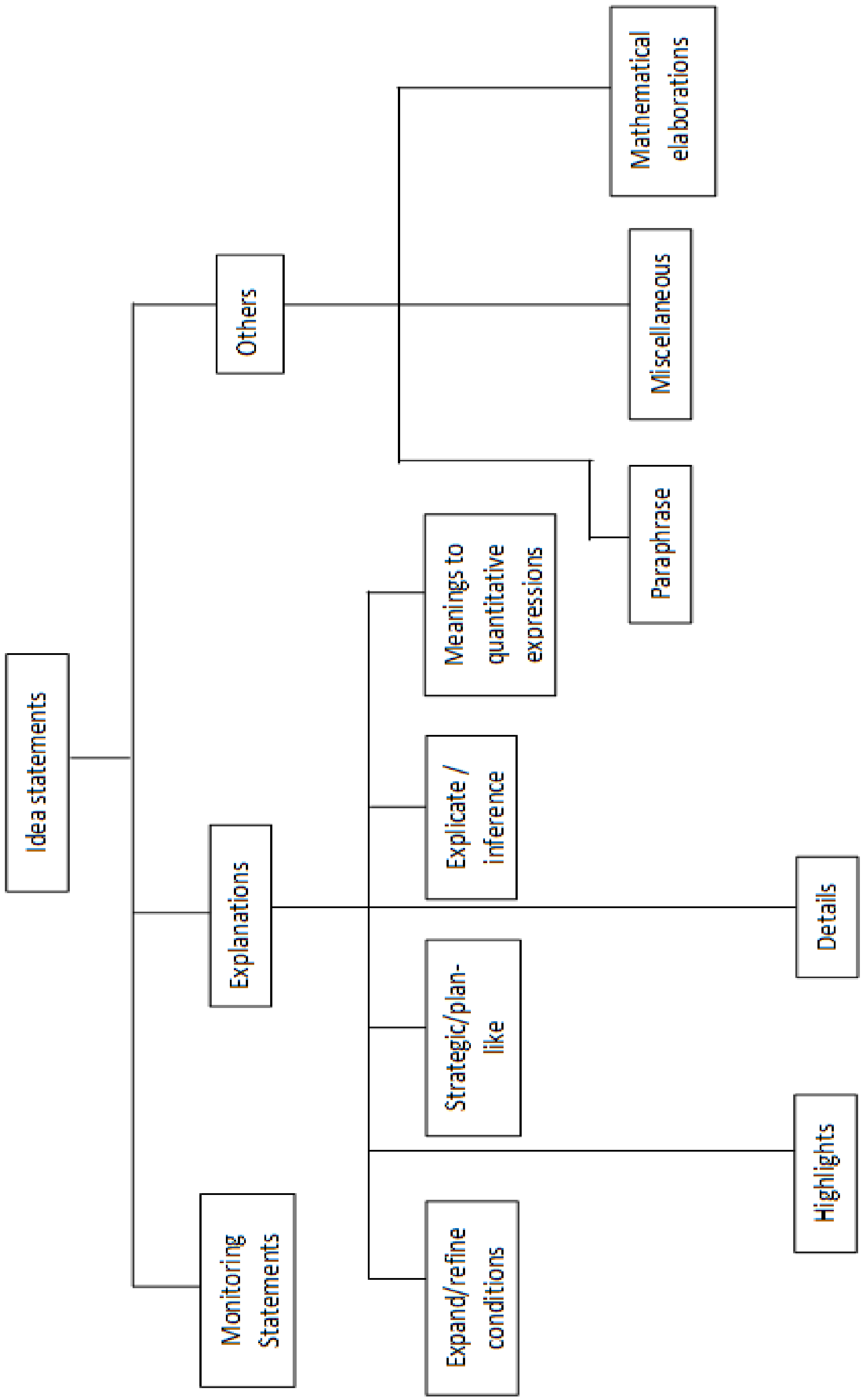

Figure 18. Coding schemes for the analysis of the protocols

The initial (first) broad coding schemes as suggested by Chi et al. (1989, 1991) are:

a) self-explanations – these are comments that pertain to the content of physics but are not paraphrases of the ECT. For example, this statement made by a participant qualifies as a self-explanation: “resistors in series allow current to flow in one direction while……….”

b) monitoring statements – these are comments on the states of participants’ understanding of the contents of the ECT. For example, this comment qualifies as a monitoring statement: “ok..ok..what I understand about this is the current flowing through the circuit and different currents are flowing”.

c) miscellaneous (which included paraphrases and mathematical manipulations) – these are comments which are paraphrases or reread of the ECT or comments pertaining to mathematical elaborations. For example, this comment was coded as miscellaneous: “we have the standard / fixed and the variable resistor”.

Table 9 below is a transcript of one participant’s protocol in which a line number was assigned to each statement corresponding more or less to a phrase.

Table 9

Transcript of an example self-explanation protocol and idea classification

	Idea statements	Protocol lines
I.	Explanation	1. The cell the switch and the ammeter are connected

II.	Miscellaneous	2. I will learn how to add resistor in a circuit¸ will learn how to get 100% accuracy for resistors connected in parallel, I will also learn how to connect a battery, light bulb and switch.
		3.The description for resistors in parallel and series value cannot be changed
		4. The resistor is a component designed to offer resistance to the flow of direct current in circuit and
		5. are made of wires in different diameters.
III.	Monitoring	6. It may be 6 wires connected together to light the bulb.
IV.	Miscellaneous	7. We have the standard / fixed and the variable resistor
V.	Explanation	8. I can see the animation with two resistors connected in parallel and
VI.	Explanation	9. the charges are flowing to the left direction,
		10. I think the moving dots represent the charges.
		11. This other one represent resistors in series
		12. The charges from the resistor are flowing in one direction to the cell.
		13. When resistors are connected in series they will be on a straight line and
		14. current will be flowing in one direction.
VII.	Miscellaneous (incorrect explanation)	15. When in parallel they will be arranged in steps and
		16. voltage across each of them is different and current will be the same
VIII.	Explanation	17. When resistors are arranged in series current are the same with different voltage.
IX.	Miscellaneous	18. Formula for resistors in series will be V_1+V_2+V_3 ------------------- Equation 1
		19. Ohms law says $V_1 = IR_1$ and $V_2 = IR_2$
		20. If connected in series the effective resistance

		equal sum of the different resistors
		21. Resistors in series allows current to flow in one direction while
		22. current flows in different directions when resistors are connected in parallel
		23. This is resistors in parallel and
		24. it shows the cell and the direction of the electron

A science education lecturer at the faculty of education of a university in Lagos, who acted as an independent rater, repeated the coding procedure on one-third of the verbal data to get an inter-rater reliability coefficient. The inter-rater reliability coefficients calculated for each school were school A 93%; school B 96%; school C 97%; and school D 94. The overall score agreement was 95%.

6.2.1 Encoding for the learning process and content domains

In the second type of coding, the coding schemes suggested by Chi *et al.* (1989, 1991) were applied to only the self-explanation segments in order to answer the first research question. The reason for limiting them was because the self-explanation segments pertain to the content of physics. The codes are “(1) strategic, plan-like or goal oriented, (2) expand or refine preconditions, (3) explicate consequences of actions, and (4) give meaning to quantitative expressions”. It was predicted that participants in the speech cueing groups would generate a greater number of self-explanations according to the criteria specified in Chi *et al.* (1989, 1991). Using the coding schemes, relevant process segments from the participants' self-explanations were classified within the four statement types without reference to the specific components of the task. The four statement types have been documented in the peer-reviewed research (Chi *et al.*, 1989, 1991) and are therefore considered the well-specified, predetermined criteria. The four types are explained below:

Strategic, plan-like or goal oriented (Chi *et al.*, 1989, 1991) imply a cause of action without necessary mindfulness of the information. The following segment would qualify under the strategic or goal oriented self-explanation category:

> I need to connect the wire to the negative terminal of the battery.

*Expand or refine preconditions (*Chi *et al.*, 1989, 1991*)* imply the elaboration of the preconditions in the instructional unit. The following segment would qualify under this category:

> So, she wants me to create my circuit first before drawing the schematic diagram.

Explicate consequences of actions (Chi *et al.*, 1989, 1991) are statements relevant to a presentation using one's general knowledge, such as generating inferences. For example, if the instruction is to “place the ammeter in series with the circuit, and place the voltmeter in parallel with the circuit”; the following segment would qualify under this category:

> I placed the ammeter in series with the circuit while I placed the voltmeter in parallel with the circuit because if I connected the ammeter in parallel, a higher current will pass through it thereby blowing it up.

Give meaning to quantitative expressions (Chi *et al.*, 1989, 1991) indicate contextualizing a quantitative expression in order to make it more meaningful or understandable. The following segments qualify under this category:

> If the total p.d. across R_1, R_2 and R_3 is given as V, it means that $V = V_1 + V_2 + V_3$.

Table 10 below is a sample of a participant's self-explanation protocol. The monitoring statements and miscellaneous statements (paraphrases and mathematical elaborations) have been excluded because the plan was to code only the self-explanation for the second type of coding. Line numbers were assigned to each statement corresponding more or less to a phrase.

Table 10

Sample of a participant's self-explanation protocol and coding

	Categories of self-explanation	Verbal Protocols
I.	Explicate/infer consequences	1) Ok…silence…hmmmm… 2) this is a cell, a switch. 3) A cell is actually connecting a wire to the switch and 4) the wire from the switch to the battery and 5) what I see again is another circuit…. 6) a sketch of a circuit..yea! yap!
	Researcher:	7) Don't keep quiet. Keep saying it out.
II.	Explicate/infer consequences	8) What I see here is a battery connecting to two globes in A and in series. 9)There is a series connection in A and 12) in B the battery and two globes are in parallel connection
	Researcher:	This is just to check your prior knowledge. If you can remember anything, if you cannot remember it's not compulsory that you answer the questions. So, you can

		continue.
III.	Refine/expand conditions	13) Is about resistors is in parallel when they flow apart..they are not on the same line 14) when resistors are arranged in series the effective resistance is the sum of the different resistors….ok…ok…
IV.	Refine/expand conditions	15) ok..ok..what I understand about this is the current flowing through the circuit and 16) different currents are flowing
V.	Refine/expand conditions	17) Some of the currents are flowing through the 30 Ohms while 18) others get along to flow through the 10 Ohms resistor.
VI.	Give meaning to quantitative expressions	19) This diagram is showing three resistors connected in parallel and 20) therefore the same voltage across the resistors…., 21) current is equal to voltage over resistance.
VII.	Strategic/plan-like	22) This is a battery…..pause 23) I will connect wires to the negative and positive terminals of the battery.
VIII.	Strategic/plan-like	24) I'm going to place a battery first then 25) the wires then the bulb.
IX.	Strategic/plan-like	26) I will pick a wire, wire… 27) then a battery…battery, place it here. 28) Then wire here. Make another wire. 29) Pick another wire then umm….
X.	Explicate/infer consequences	30) yeah…battery, a wire, another wire, then a light bulb, another wire 31) because the circuit is connected in series
	Researcher:	What are you trying to do?
XI.	Strategic/plan-like	32) I want to make the wire straight. 33) Bring out another wire. 34) Then bring out the switch. 35) ok…bring another wire…
XII.	Refine/expand conditions	36) because I need a switch to control the circuit 37) so then I put on the switch 38) Ok. I made a circuit and it's 9V..yeah 9volts…..
XIII.	Give meaning to quantitative expressions	39) It means the voltage in this circuit is 9volts.

Furthermore, in order to mitigate the problem that may arise when more self-explanations may be taken as equivalent to better attentional focus, the self-explanations were further examined and coded according to specific components of the task. The same procedure for determining content validity of the materials and test items in a previous study (Mann, 1993; 1995) and applied to the content segments used in this study. An Instructional Design expert reviewed the content during the formative evaluation stage. Concerning the criterion-related validity of the content segments, the verbalizations were coded on the type of task mentioned highlights or details. Segmented transcripts were used in coding the reports. The coders discussed the coding scheme. An overall agreement between the two coders was determined, consistent with Mann (1993, 1995):

> *Highlights Segments* refer to the main idea or epitome, also referred to as the gist in a presentation. For example, the following statements will qualify as highlight segments; “I think the ammeter should be connected in series with the circuit while the voltmeter in parallel with the circuit.”
>
> *Details Segments* refer to the elaborations on the main idea. For example, the following statements will qualify as details segments: “In order for the light bulbs to come on, I connected the negative terminal of the wire to one terminal of the light bulb and connected the positive terminal to the other terminal.”

The self-explanations constituted qualitative data which were analysed in an objective and quantifiable way using descriptive statistics (mean, standard deviation, and chi-square) and ANOVA. The expected results were that participants in the speech cueing version of the ECT would have better attentional focus by generating more self-explanations that were consistent with accepted scientific explanations. Analyses of the results of the posttests served to validate and substantiate the verbal data collected.

6.3 Results

Results of the study as shown in the table of descriptive statistics below (table 18) revealed that multimedia in electric circuits improved learners' performance. However, there were no significant differences between convergent temporal speech cueing, narrated screen text, and on-screen text groups in the posttest and delayed posttest. The researcher used an alpha level (p) of .05 for all statistical tests. The three research questions that guided this dissertation are answered below.

Research question 1: How do Ilorin Senior Secondary School (SSS) (grade 11) students in the convergent temporal speech cueing group, narrated screen text group, and on-screen text group differ in their attentional focus on the electric circuits tutorial?

In order to answer the first research question, the audio recordings of 30 participants' self-explanation in the validation and experiment stage were transcribed and coded. These 30 participants from the 51 participants in the third stage of the formative evaluation process were selected from the four schools. Nine participants were selected from school A, nine participants were selected from school B, nine participants were selected from school C, and three participants were selected from school D. These were the participants whose audio recordings were audible enough to be transcribed. The audio recordings of the remaining 21 participants were inaudible. The breakdown of participants showed that 10 participants were in each of the three experimental groups - convergent temporal speech cueing group, narrated screen text group, and on-screen text. The unit of analysis (n = 221) is the number of self-explanations made by the participants. The breakdown of the self-explanations in each category is shown in table 10 below.

Table 11

Number of self-explanations generated

Groups (Multimedia Attribute)	Self-explanations				Total
	Strategic /plan-like	Expand/ Refine Preconditions	Explicate consequences of Action	Give Meanings to Quant. Expressions	
Narration	2	1	2	2	7
Narration	3	2	2	2	9
Narration	1	1	2	1	5
Narration	3	2	3	2	10
Narration	1	1	2	2	6
Narration	1	2	3	2	8
Narration	2	1	2	3	8
Narration	2	2	1	2	7
Narration	1	2	2	2	7
Narration	2	1	1	2	6
On-screen	1	2	0	1	4

On-screen	2	1	1	1	5
On-screen	1	1	2	1	5
On-screen	1	0	1	2	4
On-screen	0	0	0	0	0
On-screen	0	1	1	2	4
On-screen	1	2	1	1	5
On-screen	1	1	0	1	3
On-screen	1	0	0	1	2
On-screen	2	1	1	0	4
Sound cues	4	2	3	3	12
Sound cues	1	2	1	1	5
Sound cues	2	4	2	3	11
Sound cues	3	3	2	4	12
Sound cues	4	3	2	4	13
Sound cues	3	3	2	3	11
Sound cues	3	4	2	3	12
Sound cues	2	3	4	2	11
Sound cues	3	4	4	3	14
Sound cues	2	3	2	4	11

Chi-square test of independence was used to test if there exists independence or not between modality (multimedia attribute) and attentional focus (operationalised as quality self-explanations according to the criteria by Chi et al.). This was necessary because the self-explanation data constituted frequency data that was treated as statement counts rather than as ratio data. In order to use the Chi-square model, the researcher adopted four steps: (1) stated the hypotheses, (2) formulated an analysis plan, (3) analysed the sample data, and (4) interpreted the results.

The research question was stated in hypothesis format:

The null hypothesis H_o was: modality and attentional focus are independent

The alternative hypothesis H_a was: modality and attentional focus are not independent.

The significance level was set at a value of 0.05, consistent with most research adopting the quantitative research analysis approach. In order to analyse the self-explanation data, the SPSS statistical package was used. The table below shows the results of the chi-square test of independence.

Table 12

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	51.600[a]	26	.002
Likelihood Ratio	56.414	26	.000
N of Valid Cases	30		

The results of the Pearson Chi-Square test in table 10 shows that the relation between the modality (multimedia attribute) and attentional focus was significant, X^2 (2, N = 30) = 51.600, p <.05. Since the p-value is less than the significance level of 0.05, the null hypothesis was rejected. Therefore, the alternative hypothesis H_a that states that modality (multimedia attribute) and attentional focus are not independent was upheld. This result shows that there is a relationship between multimedia attribute and attentional focus. That is, the manner in which the multimedia materials was designed influenced the participants' attention.

Further analysis was conducted on the self-explanation data to establish if there were any between group modality effects. Results of the ANOVA on the self-explanation data revealed statistically significant difference in the attentional focus of the participants in the three experimental groups. Table 13 below shows the results of the ANOVA tests.

Table 13

ANOVA Tests on the self-explanation data

	(I) Experimental Conditions	(J) Experimental Conditions	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tukey HSD	Narration	Onscreen	3.70*	.835	.000*	1.63	5.77*
		SoundCues	-3.90*	.835	.000*	-5.97	-1.83*
	Onscreen	Narration	-3.70*	.835	.000*	-5.77	-1.63*
		SoundCues	-7.60*	.835	.000*	-9.67	-5.53*
	SoundCues	Narration	3.90*	.835	.000*	1.83	5.97*
		Onscreen	7.60*	.835	.000*	5.53	9.67*
Scheffe	Narration	Onscreen	3.70*	.835	.001*	1.54	5.86*
		SoundCues	-3.90*	.835	.000*	-6.06	-1.74*
	Onscreen	Narration	-3.70*	.835	.001*	-5.86	-1.54*
		SoundCues	-7.60*	.835	.000*	-9.76	-5.44*
	SoundCues	Narration	3.90*	.835	.000*	1.74	6.06*
		Onscreen	7.60*	.835	.000*	5.44	9.76*

The Scheffé analysis revealed that convergent temporal speech cueing group, the narrated screen text group, and the on-screen text group were significantly different from each other in their attentional focus. The mean self-explanations for the convergent temporal speech cueing group was significantly higher than the other two groups. Similarly, the mean self-explanations for the narrated screen text group was significantly higher than the on-screen text group.

Table 14. Multiple Comparisons

Dependent Variable: Self-Explanation

	(I) Group Representation	(J) Group Representation	Mean Difference (I-J)	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Tukey HSD	Narration	On-screen	4.200*	.000	2.45	5.95
		Sound cues	-4.000*	.000	-5.75	-2.25
	On-screen	Narration	-4.200*	.000	-5.95	-2.45
		Sound cues	-8.200*	.000	-9.95	-6.45
	Sound cues	Narration	4.000*	.000	2.25	5.75
		On-screen	8.200*	.000	6.45	9.95
Scheffe	Narration	On-screen	4.200*	.000	2.37	6.03
		Sound cues	-4.000*	.000	-5.83	-2.17
	On-screen	Narration	-4.200*	.000	-6.03	-2.37
		Sound cues	-8.200*	.000	-10.03	-6.37
	Sound cues	Narration	4.000*	.000	2.17	5.83
		On-screen	8.200*	.000	6.37	10.03

*. The mean difference is significant at the 0.05 level.

The self-explanation protocols were further coded as highlights or details segments to check for verbosity and to validate the results obtained from the second type of coding. The table below shows the number of details and highlights statements. The analyses of the self-explanation data also revealed that participants in the three groups differed in the number of details and gist segments which they generated (see table 15 below). The other tables of results can be found in Appendix J.

Table 15

Highlights (gists) and details (verbatim) segments

Groups (Multimedia modality)	**Gist**	**Verbatim**
Narration	2	4
Narration	5	4
Narration	2	3
Narration	4	3
Narration	2	2
Narration	5	3
Narration	3	3
Narration	3	2
Narration	4	2
Narration	2	2
On-screen	1	0
On-screen	1	1
On-screen	2	1
On-screen	1	1
On-screen	0	0
On-screen	2	1
On-screen	2	1
On-screen	1	1
On-screen	1	2
On-screen	4	1
Sound cues	6	5
Sound cues	3	2
Sound cues	7	3
Sound cues	6	5
Sound cues	8	5

Sound cues	4	6
Sound cues	5	6
Sound cues	6	4
Sound cues	8	5
Sound cues	6	5

Table 16

ANOVA on the Gists and Verbatim Statements

		Sum of Squares	df	Mean Square	F	Sig.
Gists	Between Groups	98.467	2	49.233	28.283	.000
	Within Groups	47.000	27	1.741		
	Total	145.467	29			
Verbatim	Between Groups	68.467	2	34.233	40.362	.000
	Within Groups	22.900	27	.848		
	Total	91.367	29			
Total Statements	Between Groups	328.467	2	164.233	44.122	.000
	Within Groups	100.500	27	3.722		
	Total	428.967	29			

Research question 2: How do the Ilorin SSS students (grade 11) in the three groups differ in their performance following the intervention with the Electric Circuits Tutorial? “Performance on electric circuits” is operationalized as the number of correct answers on an immediate post-test (Appendix H).

Results of an analysis of variance on the pretests data failed to reveal any statistical differences between the three groups. In practical terms, it was expected that pretest scores would be low and roughly equivalent across treatment conditions since the participants had not encountered the electric circuits’ tutorial before this research. The table below shows the modeling adopted for the analysis of the results of the validation and experiment stage (the mean scores are expressed in percentages).

Table 17

Modelling used for data analyses (ANOVA)

	Independent variable (Multimedia attribute)	Covariate (Pretest Mean Scores)	Posttest Mean Scores	Delayed posttest Mean Scores
Level 1	Narration	27.65	35.88	25.29
Level 2	On-screen text	22.06	32.94	25.59

Level 3	Speech cues	21.47	37.94	30.88

6.3.1 Posttest and Delayed Posttest Data

Analyses were run on the post-test and delayed posttest data. An analysis of variance (ANOVA) was calculated on the post-test data. Next, a repeated measures analysis of covariance (MANCOVA) was calculated on the posttest and delayed posttest data using the pretest as the covariate. Third, descriptive statistics were computed on the posttest and delayed posttest scores.

The rationale for implementing a multivariate test on the data was that the groups in the study may differ in some respect due to interrelated differences in their background (Gall, Gall & Borg 2006; Paivio et al, 1989). Moreover, multivariate tests measuring learning effects from visual and verbal cues in multimedia instruction have been implemented in previous dissertation research (Steffey, 2001). Similarly, multivariate tests were used in another doctoral dissertation research, which sought to investigate whether visual cues and self-explanation prompts were effective in multimedia learning (Lin, 2011). Covariate measures have also been suggested, even when experimental groups do not differ significantly (Frigon & Laurencelle, 1993).

> Covariance can correct biases due to pre-existing differences between groups...and increase the precision of estimation and the statistical power by reducing the error variance (Frigon & Laurencelle, 1993, p. 2).

To answer the second research question, the results of the post-test immediately preceding the validation stage were analysed using descriptive statistics (mean, standard deviation) and ANOVA. Individual differences were analysed by comparing the performance of the participants in the convergent temporal speech cueing vs. narrated screen text vs. on-screen text groups using a repeated measures analysis of variance. All the problems in the post-test were assigned equal weight to ensure uniformity and ease of scoring; this was done in conjunction with the physics teachers for inter-rater reliability across the analyses. These results served to correlate attentional focus with better scores in the posttests and to give supportive evidence to the durability of sound.

Table 18

Descriptive statistics on the pretest, posttest and delayed posttest

Descriptive statistics			
Treatment (20 items)	Pretest (n=51)	Post-test (n=51)	Delayed Post-test (n=51)
TEXT GROUP	(n = 17)	(n = 17)	(n = 17)
M	22.06	32.94	25.59
SD	4.35	11.46	12.73
Std. Error	1.06	2.78	1.56
NARRATED TEXT	n = 17	n = 17	n = 17
M	27.65	35.88	25.29

SD	8.12	10.93	12.93
Std. Error	1.31	2.65	1.97
SPEECH CUES	(n = 17)	(n = 17)	(n = 17)
M	21.47	37.94	30.88
SD	7.93	8.67	11.49
Std. Error	2.26	2.10	2.79

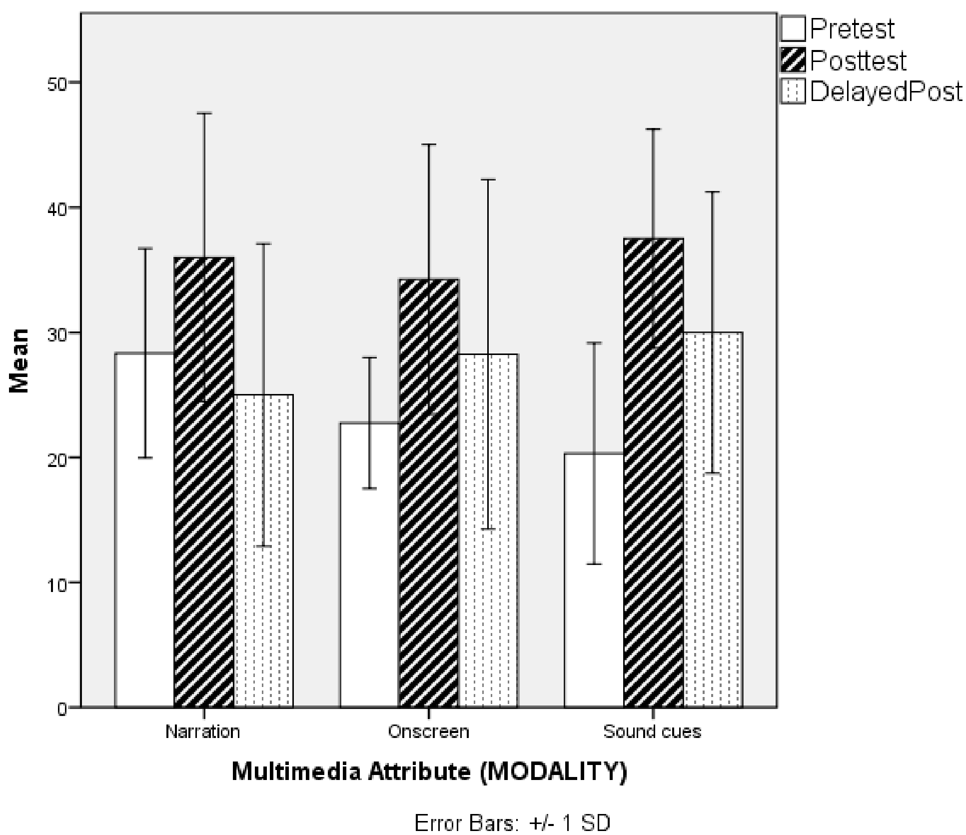

Figure 19: Comparisons of the three experimental groups

Table 19

Tests of Within-Subjects Contrasts

Source	Pos_Del	Type III Sum of Squares	df	Mean Square	F	Sig. of F
Pos_Del	Linear	54.955	1	54.955	.474	.495
Pos_Del * Pretest	Linear	27.642	1	27.642	.238	.628
Pos_Del * group	Linear	32.326	2	16.163	.139	.870
Error(Pos_Del)	Linear	5448.828	47	115.933		

The results of the analyses indicate that there was a statistically significant difference within the groups. However, the results show that between groups modality effect was non-significant. That is, the ANOVA on these data failed to reveal any statistically significant treatment effects between the groups as shown in table 20 below. The other tables of results can be found in Appendix J.

Table 20. Multiple Comparisons

Post Hoc Tests	(I) Group Representation	(J) Group Representation	Mean Difference (I-J)	Std. Error	Sig. of F	95% Confidence Interval Lower Bound	Upper Bound
Tukey HSD	Narration	On-screen	2.75	2.271	.454	-2.75	8.24
		Sound cues	-.49	2.271	.975	-5.98	5.00
	On-screen	Narration	-2.75	2.271	.454	-8.24	2.75
		Sound cues	-3.24	2.271	.337	-8.73	2.26
	Sound cues	Narration	.49	2.271	.975	-5.00	5.98
		On-screen	3.24	2.271	.337	-2.26	8.73
Scheffe	Narration	On-screen	2.75	2.271	.487	-2.99	8.48
		Sound cues	-.49	2.271	.977	-6.23	5.25
	On-screen	Narration	-2.75	2.271	.487	-8.48	2.99
		Sound cues	-3.24	2.271	.370	-8.97	2.50
	Sound cues	Narration	.49	2.271	.977	-5.25	6.23
		On-screen	3.24	2.271	.370	-2.50	8.97

Based on observed means.
The error term is Mean Square(Error) = 43.852.

Research question 3: How do the Ilorin SSS students (grade 11) in the three groups differ in their learning of electric circuits after the latency period of six weeks? “Learning of electric circuits” is operationalized as a permanent change in performance measured by the number of correct answers on a delayed post-test (Appendix H), six weeks after the intervention.

To answer this research question, the results of the delayed post-test (after a latency period of six weeks) were analysed using descriptive statistics (mean, standard deviation) and ANOVA. Individual differences were analysed by comparing the performance of the participants in the convergent temporal speech cueing, the narrated screen text, and the on-screen text groups by using ANOVA. The delayed post-test contained the same items as the immediate post-test; however, the items were re-ordered to mitigate the effect of prior knowledge. All the problems in the delayed post-test were assigned equal weight to ensure uniformity and ease of scoring.

It was envisaged that the data collected from the participants during the validation stage will correlate with the performance of the participants in the immediate and delayed posttest. That is, the participants who had better attentional focus operationalised as providing more self-explanations would perform better on both the immediate and delayed posttest as evidenced by the presence of an auditory trace in the speech cueing group as observed by Mann (1997).

However, the results of the analysis, as shown in the table below, on the delayed posttest data failed to reveal any statistically significant treatment effects between the experimental groups. This analysis was a repeated measures on the posttest and delayed posttest by treatment using the pretest score as covariate ($n = 51$).There was a significance level of $p = .158$ for the delayed posttest, with a group factor of 2 degrees of freedom, leaving 48 in the error term. The other tables of results can be found in Appendix J (tables 34-39).

Table 21. Parameter Estimates

Dependent Variable	Parameter	B	Std. Error	t	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Posttest	Intercept	32.597	4.933	6.607	.000	6.607	6.607
	Pretest	.249	.198	1.259	.214	1.259	1.259
	[Narration]	-3.596	3.758	-.957	.344	-.957	-.957
	[On-screen]	-5.146	3.556	-1.447	.155	-1.447	-1.447
	[SoundCues]	0[a]	.	.	.	.	.
Delayed Post	Intercept	28.584	5.952	4.802	.000	4.802	4.802
	Pretest	.107	.239	.449	.656	.449	.449
	[Narration]	-6.250	4.535	-1.378	.175	-1.378	-1.378
	[On-screen]	-5.357	4.291	-1.248	.218	-1.248	-1.248
	[SoundCues]	0[a]	.	.	.	.	.

*. The level of significance is at the 0.05 level.

6.4 Summary

This chapter of the doctoral dissertation was a description of the validation stage of the ECT and the experiment with 51 participants. During the experiment, participants self-explained as they used the ECT and the PhET Circuit Construction Kit (CCK) interactive simulation. The steps involved in the validation stage were the sequential training, training on verbal protocols, and the actual task performance involving the use of the tutorial. The method adopted for the analyses of the verbal protocols was described in chapter five. The analysis followed a 3-step method consistent with most qualitative research works: transcribing the video and audio recordings, segmentation and coding. Chapter six was also a description of the method adopted for analyzing the data and results. Three types of coding were adopted for the analyses of the verbal transcripts. The results showed a dependence between the self-explanations and the student's attentional focus.

Chapter seven will present the discussion, conclusion, and the practical implications emanating from the research and the future research directions.

7. DISCUSSION, CONCLUSION, AND IMPLICATIONS

Chapter seven of this doctoral dissertation is a general summary of the research, the conclusion and the practical implications of the research. Chapter seven is also a discussion of the results obtained from the field work, a discussion of the limitations, and future directions.

Summary of research findings

The findings of the research from the verbal data that relate to Nigerian students' attentional focus and the quantitative research findings that relate to the research questions on participants' achievement in the posttest and delayed posttest are listed below and discussed thereafter. The findings are:

- Statistically significant differences were found in Nigerian students' attentional focus between the narrated screen text group, temporal speech cueing group and on-screen text group. The temporal speech cues group was superior to the narrated screen text group and the on-screen text group. Likewise, the narrated screen text group was superior to the on-screen text group.
- The analysis of the immediate posttest achievement scores between the three experimental groups failed to show any statistical significance.
- The analysis of the delayed posttest achievement scores between the three experimental groups failed to show any statistical significance.

Results of the research revealed that participants in the speech cueing experimental group had better attentional focus as indicated by the quality of their scientific self-explanations of electric circuits compared to the on-screen text treatment group and the narrated-text treatment group. This result is consistent with the findings of Roy and Chi (2005) which reported that multimedia learning environments have been more *stimulating and supporting* to self-explanation than text-only learning situation. The results of this research revealed that the participants generated different levels of self-explanation. This finding is consistent with the report of the literature reviewed by Mathews and Rittle-Johnson (2008).

Furthermore, results of the analyses of the pretest, posttest, and delayed posttest data revealed no statistical significant differences between the three experimental groups. This research failed to support previous research on the modality effect in multimedia learning such as Mayer's research on the modality principle and Sweller, van Merrienboer and Paas' (1998) research on the modality effect. Neither did the findings of the research support Mann's structured sound function (SSF) model.

It is easy to speculate why the temporal speech cues and the narrated text did not have the expected significant effects on the posttest and delayed posttest scores of the participants. Perhaps there are too many unidentified and uncontrolled variables. Perhaps the non-significance of the results may be as a result of allowing the learners to control the pacing of the multimedia instruction, consistent with the findings of Tabbers, Martens and van Merrienboer (2004) and Witteman and Segers (2010). Perhaps, it could also be as a result of the length of the texts in the multimedia instruction (Rummer, Schweppe, Furstenberg, Scheiter & Zindler, 2011).

Perhaps the statistical and research techniques are simply not effective enough or perhaps a different kind of attention was being measured.

Current research in the cognitive disciplines, supported by research in neuroscience identified three types of attention ─ orienting, alerting, and the executive control of attention systems (Posner & Rothbart, 2007). “Alerting” is defined as achieving and maintaining a state of high sensitivity to incoming stimuli (Posner & Rothbart, 2007), such as the ones used in event notification software. The orienting system concerns the selection of information from sensory input. Orienting involves aligning attention with a source of sensory signals. “Orienting can be manipulated by presenting a cue indicating where in space a target is likely to occur, thereby directing attention to the cued location” (Posner & Rothbart 2007, p. 7). The executive attention system resolves conflicts among thoughts, feelings, and responses.

The body of research on multimedia learning over the past decades has been with mixed results. This research appears to have further upheld the findings of the status quo. Other extraneous factors may have been responsible for the uncorrelated attentional focus and achievement scores. For example, below-average senior secondary school students in Nigeria reported that they enjoyed learning from the ECT but the multimedia “pleasing effect” to most SSS students may have been responsible for the negatively correlated attentional focus and achievement scores. The “pleasing effect” is a feeling of satisfaction or enjoyment derived from multimedia learning (Clark & Feldon, 2005). Additionally, the timing of the research may have also affected the findings. The research was conducted outside of the lesson schedule, which may have affected student attitudes and motivation toward learning.

7.1 Conclusions of the Research

Multimedia learning environments provide learners with an opportunity to experience learning and construct knowledge using different presentation modes and processing learning materials using different sensory modalities. Therefore, the media-mix should be adequately considered when designing for modality principle. The various presentation modes have their advantages and each of them may be preferred or found more appropriate by the student. A detailed instructional analysis should identify the proportion of text, speech cues or narration that may be included in the multimedia learning environment.

The second conclusion of the study is that when designing multimedia instruction for below-average senior secondary school students in Ilorin metropolis or any population with similar characteristics, research should be carried out to determine the students' learning preference. Both the convergent temporal speech-cueing described in the Structured Sound Function (SSF) model of instructional design, and Mayer's (1997) cognitive theory of multimedia learning have their place in instructional multimedia.

The third conclusion of the research is that below-average senior secondary school students in Nigeria should have increased access to curricular multimedia designed for them. The curricular multimedia should be formatively evaluated to improve its effectiveness. The students should be taught the subject content covered in the multimedia tutorial before using the computer-based tutorial for possible greater effect.

Additionally, the fourth conclusion that emanated from this research is that instructional design guidelines of multimedia learning environments need to be re-examined. It would seem that the design guidelines are not as hard and as fast as an instructional designer might like. On the other hand, until more evidence that is factual or better research is possible, one might be perfectly justified in pursuing an intuitive approach to instructional design.

7.2 Limitations of the Research

Observations of the participants by the researcher and the research assistants during the validation of the ECT and experimental testing revealed several possible limitations and possibilities for further research.

The first limitation of the research is that the results must be generalized with caution because four schools of convenience located in Ilorin metropolis were used. The participating schools have a structured program in which the field trial of the electric circuits' tutorial had to fit into. There were 2 day schools and two boarding schools. The day schools started their lessons at 8:00 am and ended at 2:00 pm with two breaks – one short break of 10 minutes and another longer break of 30 minutes. The boarding schools started their daily activities at 7:00 am and ended 9:30 pm, with several activities within this period. In School A (private, university-owned), the experiment for this research was scheduled during the long break, and extended to the last lesson. In School B (government owned and publicly funded), the experiment for this research was scheduled during a physics lesson period. In School C (privately owned), the experiment for this research was scheduled after the lesson periods (4:00 pm). In School D (missionary school), the experiment for this research was scheduled after first term examinations. It may have been easier and more systemic if the schools had allocated a dedicated time for the validation research.

The second limitation of the study is that of unstable electric power supply around the time the experiment could be carried out. For example, the two boarding schools did not have a standby generator that was readily available to the researcher. On the few occasions that the schools allowed the researcher to use the generators, the researcher had to buy premium motor spirit (gas) for the school generators. Similarly, the lack of adequate computers for this research was a limitation for the success of the students. It was apparent during the experiment that improvements were needed in the software and the hardware.

The third limitation of the study is that duration of the experiment may have made the participants become weary during the validation and experiment of the ECT. The experiment took place after the participants had already done six lessons in the day. Future research should allow the participants to take a break during the experiment to eliminate fatigue as an intervening variable.

The fourth limitation of this research is the small sample size, which was chosen as a result of time and resource constraints, a small number of covariate variables were collected. The small sample size may be inadequate for tests such as ANOVA and ANCOVA, it may limit the generalization of the results, consistent with previous studies on multimedia learning (Stanwick, 2010).

7.3 Practical Implications of the Research

The results of this research have implications for those attempting to understand how below-average physics students in Nigerian senior secondary schools learn from speech prompts in a computer-based tutorial. This understanding is a necessary ingredient in the design of multimedia learning environment for this group of students or similar population.

The first implication that can be drawn from the results of the research was that training and practice with equivalent modality-specific software provided a more reliable baseline from which to assess modality effects.

The second implication of this research was that an appropriate choice of experimental research design improved the probability of detecting learning effects between treatments.

The third implication that can be drawn from the results of the research was that the problem of skipping, forgetting to read, and ignoring critical information from a computer could be solved with temporal cueing. A main consideration was how much information should go into a speech cue, and how much left as on-screen text? This study attempted to answer this question. Temporal cues are different in their quantity (duration) and their quality (function) from “Narrated Text” or “Spoken Text”. With below-average Physics students in Nigeria who were not familiar with multimedia for learning Physics, their attraction and preference was to any kind of multimedia – narrated text, temporal speech cues or text-only. In order to determine how much sound should be integrated in a self-paced multimedia tutorial for below-average Physics students in Nigeria, research should be carried out to establish the competence level and familiarity of the students with multimedia instructional materials. At first use, below-average senior secondary school (SSS) students in Nigeria may find the tutorial pleasing and enjoyable thereby forgetting or ignoring critical information in the tutorial.

The fourth implication of this research, which emanated from the experiment, was that below-average senior secondary school (SSS) students in Nigeria were unfamiliar with self-explanations as a cognitive learning strategy. Some of the participants considered self-explanation in a learning context as an abnormal behaviour. For example, a participant remarked after the experiment, “how can I be talking to myself? People will think I am mad”. Therefore, below-average senior secondary school (SSS) students in Nigeria should be trained in self-explanations.

7.4 Future Directions

The future direction of research in multimedia learning in Nigeria will be to examine the extent to which factors such as unstable power supply, overcrowded classrooms, and inadequate computer resources will influence students' learning from speech prompts in multimedia. In other words, a constraint-based formative evaluation should be carried out in the research.

Case studies research implementing the modality principle in multimedia learning could be carried out to examine the difference between private vs. public schools, or day vs. boarding school. Future studies could also include motivational aspect of multimedia learning - how the modality principle motivates learners to learn from multimedia. It may be important to find out if the motivational differences between physics tutorials containing speech cues, narrated text or on-screen text conditions will be significant or not.

Eysenck & Keane (2015) noted that in the real world, humans often coordinate information from two or more sense modalities at the same time, known as "cross-modal attention" (p. 183). Cross-modal attention or "the coordination of attention across modalities, namely vision and audition" (Eysenck & Kean, 2015, p. 716) may likely be the future direction with multimedia learning whereby the multimedia instructional materials would be targeted at focusing the executive system of attention network.

7.5 Summary

Chapter seven of this doctoral dissertation was a discussion of the research findings, a conclusion of the research, and suggestions for future research directions. The findings of this research revealed that the participants in the temporal speech cueing group produced significantly better quality self-explanations than the narrated text group and the on-screen text group. The posttest and delayed posttest results of the three experimental groups were not significantly different from each other. The result of this research suggests that there might be no “hard and fast rule” for instructional designers who wish to integrate speech in their multimedia learning materials. Instructional designers have the freedom to choose whichever design guidelines they prefer, without worry. This means that there is room for creativity and choice on the part of the designer.

It might be very interesting to undertake a study that would examine how participants develop self-explanations techniques in a multimedia learning environment after a period of training. Participants in the validation were not accustomed to self-explanation as a constructive learning activity that is amenable to multimedia learning environments. Even though they generated a fair amount of self-explanations, especially in the temporal cueing condition, the quality of their self-explanation was not positively correlated to performance in the posttest and delayed posttest to the extent of making a statistically significant difference between the three experimental groups.

Chapter seven was also an examination of the practical implications of this research. A significant positive educational side-effect of this research was the introduction of an improved computer-based Electric Circuits Tutorial into Nigerian secondary schools. The ECT was formatively evaluated with participants to create a multimedia material that may help to focus students’ attention when learning from a multimedia tutorial on electric circuits. Furthermore, the chapter embodies a suggestion for future research in the area of speech cues in multimedia learning for below-average senior secondary school students in Nigeria to ascertain if technology affordances contribute to the way they learn from speech cues.

The results of this study suggest that incorporating speech in multimedia learning materials may be advantageous in helping students to focus their attention on important information in the multimedia materials. However, the existing design guidelines of modality in multimedia need to be re-examined. Instructional design guidelines for multimedia seem to be far more difficult to come by, and in fact might be impossible.

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APPENDICES

Appendix A: Glossary Terms and Concepts

Key Definitions

Attentional Control Theory of Multimedia Learning: A descriptive theory of multimedia learning which describes the role of speech cues in multimedia learning.

Auto-tutorial: This is a tool designed as a self-paced learning material which contains a step-by-step instruction on how to accomplish a task.

Below-average students: These are students who attain a term score that is less than the class average.

Courseware: A group or series of related materials designed to help an individual or group understand how to accomplish a task, usually for use with a computer. The tools or series of exercises contained in a courseware are geared towards achieving a particular purpose.

Cognitive load theory: This is a descriptive learning theory of how the intellectual capability of an individual may be enhanced. The theory is based on the assumption that the architecture of the human brain is in such a way that there is a limited working memory, which has two units for processing verbal and visual information, and an unlimited long-term memory. Information is exchanged between the limited working memory and long-term memory during processing.

Instructional design: Instructional Design is the systematic development of instructional specifications using learning and instructional theory to ensure the quality of instruction.

Multimedia: Presenting information to students using different modalities such as in pictures and in words.

Cueing: is the addition of non-content information that captures attention to those aspects of the instructional materials that are important, for example, using arrows, colours etc (de Koning, Tabbers, Rikers, & Paas, 2007).

Speech cueing condition: Providing cues by using sounds.

Temporal speech cueing: A temporal speech cue is spoken information provided about a future or past event that presents some highlights and details about the static or moving visuals (Mann, 1992; 1995a)

A convergent temporal speech cue is an audio file that plays when a webpage refreshes, and re-plays when the same audio file is activated by a button on a webpage. A "convergent temporal speech cue" is operationalized as either a pre-recorded instruction, navigational direction, hint, feedback, or a reminder, spoken by a natural young female voice (Mann, 1992, 1997b, 2002).

Appendix B: Ethics Consideration

One of the methods of data collection, which involves many ethical considerations, is videotaped/video-recorded observation. Videotaping an individual in a lesson raises ethical issues, which include intrusion into the lives of participants, security of video data, privacy and confidentiality of participants and access to the data (Powell et al., 2003). The tri-council policy on ethics stipulates that an informed consent be sought from an individual who will be participating in a study before the commencement of the study. Therefore, ethics clearance will be sought from the Memorial University Ethics Committee and from the Kwara State Ministry of Education.

In order to fulfill the ethical guidelines as set out by Memorial University and implemented by the ethics committee, appropriate permission will be obtained to carry out the research. Informed consent will be sought from the participants in the study including the parents. Ethics clearance must be sought before any research can be carried out according to the Tri-Council Policy. This is because every research should ensure the protection of the rights of the participants and ensure that due process is followed. Furthermore, the tri-council ethics protocol also requires that “where possible, participants must be guaranteed privacy and anonymity and their information must be treated as confidential” (MUN ethics page).

One of the responsibilities of the researcher to the participants in a research study is to ensure that they are protected from any victimization, information distortions, biases, or any other form of practices that may infringe on their rights as participants in the study, or as human beings. Therefore, I will ensure that the participants are duly informed about the research, the benefits and potential harm (if any) disclosed to them so that they may be able to make informed decision about participating or not in the research.

Memorial University Ethics Clearance

MEMORIAL UNIVERSITY

Interdisciplinary Committee on Ethics in Human Research (ICEHR)

Office of Research - IIC2010C
St. John's, NL Canada A1C 5S7
Tel: 709 864-2561 Fax: 709 864-4612
www.mun.ca/research

ICEHR Number:	**2012-347-ED**
Approval Period:	**June 29, 2012 – June 30, 2013**
Funding Source:	MUN **Going Global Grant**
Responsible Faculty:	Dr. Bruce Mann Faculty of Education
Title of Project:	*Design, Development, Formative Evaluation, and Protocol Analysis of a Multimedia Learning Environment on 'Electrical Circuits' in a Climate of Limited Access to Computers and Unreliable Power Supply*

June 29, 2012

Mr. Kayode Arowolo
Faculty of Education
Memorial University of Newfoundland

Dear Mr. Arowolo:

Thank you for your email correspondence of May 24, June 21 and 26, 2012 addressing the issues raised by the Interdisciplinary Committee on Ethics in Human Research (ICEHR) concerning the above-named research project.

The ICEHR has re-examined the proposal with the clarification and revisions submitted and is satisfied that concerns raised by the Committee have been adequately addressed. In accordance with the *Tri-Council Policy Statement on Ethical Conduct for Research Involving Humans (TCPS2)*, the project has been granted *full ethics clearance* to June 30, 2013.

Once obtained, please forward a copy of the permission granted by the school principals and board directors to the ICEHR for our records.

If you intend to make changes during the course of the project which may give rise to ethical concerns, please forward a description of these changes to Theresa Heath at icehr@mun.ca for the Committee's consideration.

The TCPS2 requires that you submit an annual status report on your project to the ICEHR, should the research carry on beyond June 30, 2013. Also to comply with the TCPS2, please notify us upon completion of your project.

We wish you success with your research.

Yours sincerely,

Gail Wideman, Ph.D.
Vice-Chair, Interdisciplinary Committee on
Ethics in Human Research

GW/th

copy: Supervisor – Dr. Bruce Mann, Faculty of Education
Director, Office of Research Services
Associate Dean, Graduate Programs, Faculty of Education

MEMORIAL UNIVERSITY

ICEHR Clearance 2012-347-ED- EXTENDED

smmercer@mun.ca <smmercer@mun.ca> Tue, Jun 19, 2015 at 4:10 PM
To: "Mr. Kayode Arowolo (Principal Investigator)" <kma660@mun.ca>
Cc: "Dr. Bruce Mann (Supervisor)" <bmann@mun.ca>, smmercer@mun.ca

Interdisciplinary Committee on Ethics in Human Research (ICEHR)

Dear Mr. Arowolo ,

Thank you for your response to our request for an annual status report advising that your project will continue without any changes that would affect ethical relations with human participants.

On behalf of the Chair of ICEHR, I wish to advise that the ethics clearance for this project has been extended to June 30, 2016. The *Tri-Council Policy Statement on Ethical Conduct for Research Involving Humans* (TCPS2) requires that you submit an annual update to ICEHR on your project, should the research carry on beyond June 30, 2015. Also, to comply with the TCPS2, please notify us upon completion of your project.

ICEHR Ref. No.	2012-347-ED
Project Title:	(2012-347-ED) Learning from speech prompts in a computer-based tutorial on electric circuits
PI:	Mr. Kayode Arowolo Faculty of Education
Supervisor:	Dr. Bruce Mann
Clearance expiry date:	June 30, 2016

We wish you well with the continuation of your research.

Sincerely,
Susan Mercer
Secretary, ICEHR

Appendix C: Consent forms

Letter to the Principal

Title: **Learning from speech prompts in a computer-based tutorial on electric circuits**.

Researcher: Kayode Arowolo,
Faculty of Education,
Memorial University of Newfoundland,
St. John's, Canada.
Cell: 709-725-3859
kma660@mun.ca

Supervisor: Dr. Bruce Mann (Professor)
Email: bmann@mun.ca

Dear Principal,

My name is Kayode Mathews Arowolo, a full-time Doctoral candidate at Memorial University, St. John's, Canada. As part of the requirements for the award of a Doctor of Philosophy degree in Science Education, I am carrying out a research on how below-average students learn from speech cues in a computer-based multimedia tutorial on electric circuit designed for them.

I would like to request for your permission to use a computer-based Electric Circuits Tutorial (ECT) with the Grade 11 Physics students. I will collect data while the students think-aloud as they use the ECT, which will be **audio and video-taped**. Consent is also being sought from the students and their parents. The use of the ECT will take place in a purpose setup lab called an "explorer centre".

There will be no interruption to your normal school programme, I will follow the normal school timetable and the physics students will use the self-instructional materials after normal school sessions. The data collected will be treated with confidentiality and the name of your school, the teachers and the learners will not be used in the analysis of the data. The participants may withdraw from the study at any time.

The data collected will be kept for a minimum of five years, as per Memorial University policy on Integrity in Scholarly Research. The electronic data will be stored on a password-protected computer only and all hard copies of data such as audio and video recordings will be stored in a lock-up cabinet in my office at Memorial University. After the mandatory storage period, all data will be appropriately destroyed.

The learners will benefit from using the tutorial as it is hoped that this will help them focus their attention on important electric circuits' concepts.

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research (ICEHR) and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research (such as the way your school has been treated or the rights of your students as participants), you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at 709-864-2861.

Please do not hesitate to contact me if you require any further queries or clarifications. My contact details are:
Cell number: 709 725 3859 email: kma660@mun.ca

I look forward to your anticipated positive response.

Thank you.

Yours faithfully,

K. M. Arowolo

Letter to the School Board (Ministry of Education)

Title: **Learning from speech prompts in a computer-based tutorial on electric circuits**

Researcher: Kayode Arowolo,
Faculty of Education,
Memorial University of Newfoundland,
St. John's, Canada.
Cell: 709-725-3859
kma660@mun.ca

Supervisor: Dr. Bruce Mann (Professor)
Email: bmann@mun.ca

Dear Director,

My name is Kayode Mathews Arowolo, a full-time Doctoral candidate at Memorial University of Newfoundland, St. John's, Canada. As part of the requirements for the award of a Doctor of Philosophy degree in Science Education, I am carrying out a research on how below-average students learn from speech cues in a computer-based multimedia tutorial on electric circuit designed for them.

I would like to request for your permission to use a computer-based Electric Circuits Tutorial (ECT) with the Grade 11 Physics students from Unilorin Secondary School/C & S College/St. Anthony College/Government Secondary School. I will collect data while the students think-aloud as they use the ECT, which will be **audio and video-taped.** Consent is also being sought from the students and their parents. The use of the ECT will take place in a purpose setup lab called an "explorer centre".

There will be no interruption to the normal school programme, I will follow the normal school timetable and the physics students will use the ECT after normal school sessions. Data will be collected as students think-aloud while using the ECT. The data collected will be treated with confidentiality and the names of the school, the teachers and the learners will not be used in the analysis of the data. The participants may withdraw from the study at any time.

The data collected will be kept for a minimum of five years, as per Memorial University policy on Integrity in Scholarly Research. The electronic data will be stored on a password-protected computer only and all hard copies of data such as audio and video recordings will be stored in a lock-up cabinet in my office at Memorial University. After the mandatory storage period, all data will be appropriately destroyed.

The learners will benefit from using the tutorial as it is hoped that this will help them focus their attention on important electric circuits' concepts.

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research (ICEHR) and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research (such as the way the schools have been treated or the rights of the students as participants), you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at 709-864-2861.

Please do not hesitate to contact me if you require any further queries or clarifications. My contact details are:
Cell number: 709 725 3859 email: kma660@mun.ca

I look forward to your anticipated positive response.
Thank you.
Yours faithfully,

K. M. Arowolo

Letter to the Parent

Title: **Learning from speech prompts in a computer-based tutorial on electric circuits**.

Researcher: Kayode Arowolo,
Faculty of Education,
Memorial University of Newfoundland,
St. John's, Canada.
Cell: 709-725-3859
kma660@mun.ca

Supervisor: Dr. Bruce Mann (Professor)
Email: bmann@mun.ca

Dear Parent,

My name is Kayode Mathews Arowolo, a full-time Doctoral candidate at Memorial University of Newfoundland, St. John's, Canada. As part of the requirements for the award of a Doctor of Philosophy degree in Science Education, I am carrying out a research on how below-average students learn from speech cues in a computer-based multimedia tutorial on electric circuit designed for them.

I will like to seek your consent for your child to be part of this research. The research will involve the use of a computer-based Electric Circuits Tutorial (ECT) developed by the researcher with the Grade 11 Physics students. I will collect data while the students think-aloud as they use the ECT, which will be **audio and video-taped,** with your permission and that of your child. The use of the ECT will take place in a purpose setup lab called an "explorer centre". Participation in this research is voluntary and there will be no discrimination whatsoever on any ground for refusal to participate.

There will be no interruption of your child's normal school programme, I will follow the normal school timetable and your child will be taught with the use of the instructional materials after normal school sessions in the computer lab. During the intervention, I will record students' verbal protocols. After the intervention, I will collect data by interviewing learners and from written tests.

The data collected will be treated with confidentiality and the name of your child will not be mentioned in the analysis of the data. That is, the name and identity of your child will be protected in this study. Your child has the right to withdraw from the study at any stage and he/she will be excluded in the analysis of all data collected up to the point of withdrawal.

I will undertake to safeguard the confidentiality of the verbal protocols, but cannot guarantee that other participants in the study will do so. I will ask your child to please respect the confidentiality of the other participants by not disclosing the contents of the verbal protocols, and be aware that others may not respect the confidentiality of your child.

The data collected will be kept for a minimum of five years, as per Memorial University policy on Integrity in Scholarly Research. The electronic data will be stored on a password-protected computer and all hard copies will be stored in a lock-up cabinet in my office at Memorial University. After the mandatory storage period, all data will be appropriately destroyed.

The learners will benefit from using the tutorial as it is hoped that this will help them focus their attention on important electric circuits' concepts.

I have obtained permission for this research from the school board and the principal.

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research (ICEHR) and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research (such as the way your child has been treated or your child's rights as a participant), you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at 709-864-2861.

Please do not hesitate to contact me if you have any further queries or clarifications to make. My contact details are:

Cell number: 709 725 3859 email: kma660@mun.ca

I look forward to your anticipated positive response.
Thank you.

Yours faithfully,

K.M. Arowolo

Consent:

Your signature on this form means that:

- You have read the information about the research
- You have been able to ask questions about this study
- You are satisfied with the answers to all of your questions
- You understand what the study is about and what you will be doing
- You understand that you are free to withdraw from the study at any time, without having to give a reason, and that doing so will not affect you now or in the future.

If you sign this form, you do not give up your legal rights, and do not release the researchers from their professional responsibilities.

The researcher will give you a copy of this form for your records.

Put a tick in the appropriate boxes

☐ I give consent for my child to be audio and video taped during the lessons and the interview. Segments of audio and video showing my child may be shown at academic conferences, workshops or seminars.

☐ I give consent for audio tapes with my child in them resulting from this study to be used for purposes of research and publications, teacher-education and teacher-training programmes

☐ I give consent for videotapes with my child in them resulting from this study to be used for purposes of research and publications, teacher-education and teacher-training programmes

Your Signature:

I have read and understood the description provided; I have had an opportunity to ask questions and my questions have been answered. I consent to participate in the research project, understanding that I may withdraw my consent at any time. A copy of this Consent Form has been given to me for my records.”

______________________________ __________________________

Signature of participant's parent Date

Researcher's Signature:

I have explained this study to the best of my ability. I invited questions and gave answers. I believe that the Parent fully understands what is involved for their child to participate in the research, any potential risks of the study and that he or she has freely consented for the child to be in the research.

______________________________ __________________________

Signature of investigator Date

Telephone number: _709 725 3859

E-mail address: kma660@mun.ca

Student Consent Form

Title: **Learning from speech prompts in a computer-based tutorial on electric circuits**.

Researcher(s): Kayode Arowolo,
Faculty of Education,
Memorial University of Newfoundland,
St. John's, Canada.
Cell: 709-725-3859
kma660@mun.ca

Supervisor: Dr. Bruce Mann (Professor)

Email: bmann@mun.ca

Dear Student:

As a doctoral candidate in the Faculty of Education at Memorial University, I am conducting a research study from October 2014 to March 2015 that will involve the use of a computer-based Electric Circuits Tutorial (ECT) developed by the researcher with the Grade 11 Physics students. I will collect data while the students think-aloud as they use the ECT, which will be **audio and video-taped.**

I will like to seek your consent to be part of this research. The use of the ECT will take place in a purpose setup lab called an "explorer centre". Participation in this research is voluntary and there will be no discrimination whatsoever on any ground for refusal to participate.

If you choose to participate, you are still free to withdraw from the research at any time and to withdraw any data that pertains to you. Your grades will not be affected in any way if you choose to participate or not to participate in the research. Confidentiality will be respected and information that discloses your identity will not be released or published.

I will undertake to safeguard the confidentiality of the verbal protocols, but cannot guarantee that other participants in the research will do so. Please respect the confidentiality of the other participants by not disclosing the contents of the verbal protocols, and be aware that others may not respect your confidentiality. If you choose to participate in the study, we will ask that you consent to:

- Participating in an interview with the doctoral candidate and/or research assistant at the end of the intervention.
- Allowing the researcher or research assistant to use test scripts and verbal protocols as a source of data.
- Allowing the researcher or a research assistant to record field notes during intervention sessions or interviews.

All data collected in the research will be with confidentiality. Pseudonyms will be used as de-identifiers on all data collected. Data will be stored in the office of the principal investigator. The principal investigator and a research assistant will be the only individuals who will have access to the data. Furthermore, data transcription will be done confidentially. The data collected will be kept for a minimum of five years, as per Memorial University policy on Integrity in Scholarly Research. Within five years of completing the research, all data will be destroyed. Interviews will be conducted by the researcher and/or research assistant.

Thank you for considering my request. If you have any questions, please contact Mr. Kayode Arowolo at kma660@mun.ca or by telephone (709-725-3859).

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research (such as the way you have been treated or your rights as a participant), you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at 709-864-2861.

Sincerely,
Mr. Kayode Arowolo
Doctoral Candidate

Student Consent Form

Your signature on this form means that:

You have read the information about the research
You have been able to ask questions about this research
You are satisfied with the answers to all of your questions
You understand what the research is about and what you will be doing

You understand that you are free to withdraw from the research at any time, without having to give a reason, and that doing so will not affect you now or in the future.

If you sign this form, you do not give up your legal rights, and do not release the researchers from their professional responsibilities. The researcher will give you a copy of this form for your records.

Put a tick in the appropriate boxes

☐ I give consent to be audio and video taped during the lessons and the interview. Segments of audio and video showing me may be shown at academic conferences, workshops or seminars.

☐ I give consent for audio tapes with me in them resulting from this study to be used for purposes of research and publications, teacher-education and teacher-training programmes

☐ I give consent for videotapes with me in them resulting from this study to be used for purposes of research and publications, teacher-education and teacher-training programmes

Your Signature:

I have read and understood the description provided; I have had an opportunity to ask questions and my questions have been answered. I consent to participate in the research project, understanding that I may withdraw my consent at any time. A copy of this Consent Form has been given to me for my records."

____________________________ ____________________________

Signature of participant Date

Researcher's Signature:

I have explained this study to the best of my ability. I invited questions and gave answers. I believe that the participant fully understands what is involved in being in the study, any potential risks of the study and that he or she has freely chosen to be in the study.

_______________________________ _______________________________

Signature of investigator Date

709-725-3859
kma660@mun.ca

Appendix D: "Computer Use and Attitude" Inventory

Dear Participant:

My name is Kayode Arowolo and I am a doctoral candidate at Memorial University of Newfoundland, Canada. I am conducting a research study from October 2014 to March 2015 that will involve the use of a computer-based Electric Circuits Tutorial (ECT) developed by the researcher with the Grade 11 Physics students.

For my final dissertation, I am examining how students learn from speech prompts in a computer-based tutorial on electric circuits. Because you are a Physics student in Senior Secondary School (SS2), I am inviting you to participate in this research study by completing the attached surveys.

The following questionnaire will require approximately 20 minutes to complete. There is no compensation for responding nor is there any known risk. Copies of the dissertation will be provided to my Memorial University Supervisory Committee. If you choose to participate in this project, please answer all questions as honestly as possible and return the completed questionnaires promptly to the assigned (researcher and/or research assistant). Participation is strictly voluntary and you may refuse to participate at any time.

Thank you for taking the time to assist me in my educational endeavors. The data collected will provide useful information regarding your attitude and use of computers in learning. The data collected will help in the selection of participants for the pilot test and validation of the Electric Circuits Tutorial (ECT). Completion and return of the questionnaire will indicate your willingness to participate in this research. If you require additional information or have questions, please contact me at the number listed below.

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research (ICEHR) and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research (such as the way are being treated or your rights as a participant), you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at +1709-864-2861.

Please do not hesitate to contact me if you have any further queries or clarifications to make. My contact details are:

Cell number: +1709 725 3859 email: kma660@mun.ca

I look forward to your anticipated positive response.

This "computer use and attitude" inventory will be completed as part of the pre-test before the beginning of the experiment. Please indicate your choice by placing a tick in the column that most appropriately describes your beliefs about the statements.

SD (Strongly Disagree) D (Disagree) NS (Not Sure) A (Agree) SA (Strongly Agree)

Sam, H. K., Othman, A. E. A., & Nordin, Z. S. (2005). Computer self-efficacy, computer anxiety, and attitudes toward the Internet: A study among undergraduates in Unimas. *Educational Technology & Society, 8(*4), 2005-219.

Survey item	SD	D	NS	A	SA
1. I feel confident working on a personal computer					
2. I hesitate to use a computer for fear of making mistakes that I cannot correct					
3. If given the opportunity, I would like to learn more about and use computers more					
4. I feel computers are necessary tools in both educational and work settings					

Christensen, R. & Knezek, G., (1996). Validating the Computer Attitude Questionnaire. New Orleans: Southwest Educational Research Association Annual Conference.

Survey item	SD	D	NS	A	SA
5. I enjoy lessons on the computer					
6. I can learn more from books than from a computer					
7. I concentrate on a computer when I use one					
8. I enjoy computer games very much					
9. I know that computers give me opportunities to learn many new things					
10. I believe that it is very important for me to learn how to use a computer					

Loyd, B.H., & Gressard, C P. (1984). Reliability and factorial validity of computer attitude scale. *Educational and Psychological Measurement, 44(*2), 501-505.

Survey item	SD	D	NS	A	SA
11. Generally I would feel OK about trying a new problem on the computer					
12. The challenge of solving problems with computers does not appeal to me					
13. I think working with computers would be enjoyable and stimulating					
14. I would feel at ease in a computer class					
15. All students should have an opportunity to learn about computers at school					
16. I have access to a computer at home					
17. I have internet access at home					
18. Computers can help me learn physics					

Francis, L. J. (1993). Measuring attitude toward computers among undergraduate college students: The affective domain. *Computers & Education, 20(*3), 251–255.

Survey item	SD	D	NS	A	SA
19. I like learning on a computer					
20. Learning about computers is interesting					
21. I enjoy learning how computers are used in our daily lives					

From Jones, T. & Clarke, V. A. (1994). A computer attitude scale for secondary students. *Computers in Education, 4(*22), 315-318.

Survey item	SD	D	NS	A	SA
22. Working with computers makes me feel isolated from other people					
23. Using the computer has increased my interaction with other students					

24. Working with computers means working on your own, without contact with others					
25. Working with computers will not be important to me in my career					
26. Using a computer prevents me from being creative					
27. You have to be a “brain” to work with computers					
28. When I read a difficult text, I try to relate new concepts to concepts I already know					
29. Computers can help me in learning different school subjects					

Brockmyer, J. H., Fox, C. M. , Curtiss, K. A., McBroom, E., Burkhart, K. M., & Pidruzny, J. N. (2009). The development of the Game Engagement Questionnaire: A measure of engagement in video game-playing. Journal of Experimental Social Psychology, 45 (2009), 624–634.

Survey item	SD	D	NS	A	SA
30. I lose track of time when I play computer games					
31. If someone talks to me, I don’t hear them					
32. Time seems to kind of standstill or stop					
38. I can’t tell that I’m getting tired					
33. I lose track of where I am					
34. I don’t answer when someone talks to me					
35. I play without thinking about how to play					
36. I play longer than I meant to					

Appendix E: Questionnaire for Subject Matter Experts

<u>Directions:</u> Using the Likert Scale below answer the statements to the best of your ability. Place a tick in space that best suits what you think of each statement.

SA - Strongly Agree
A- Agree
N - Neutral
D - Disagree
SD - Strongly Disagree

Introduction

	SA	A	N	D	SD
The title page was clear.					
Contents were clear.					
The instructions for students were clear and easy to follow.					
The objectives/learning outcomes were clearly stated.					

Presentation of Information

	SA	A	N	D	SD
The different methods of presentation were adequate.					
The length of the instructional material was suitable for the content covered.					
The length of time spent on each objective was appropriate.					
The language, text quality and layout was clear for all students.					
The graphics contained in the presentation and manuals were clear (not cluttered).					
The manuals were user friendly.					

Content

	SA	A	N	D	SD
The material was well represented.					

The content covered was relevant to the students and forms part of the high school curriculum.					
Manuals contained relevant and important information on the topic covered.					
The teacher was familiar with the content.					
Questions asked were relevant to the areas covered.					
The lesson components were adequately integrated.					
The prerequisite nature of the skills and knowledge was accurately represented					

Media

	SA	A	N	D	SD
The choice of media for each module was appropriate for the material.					
The Electric Circuits Tutorial was easy to evaluate.					
The choice of media for each module was appropriate for the students.					
Media instruction was clear and easy to follow.					

Questions & Responses

	SA	A	N	D	SD
The practice exercises were easy to follow and complete at the end of each module.					
The practice exercises were relevant to the pretest.					
The exercises were related to the objectives.					
The length and frequency of the exercises was appropriate.					
The difficulty of the exercises was appropriate.					
The types of exercises were appropriate.					

Feedback

	SA	A	N	D	SD
The mode of feedback with each exercise was appropriate.					
The amount of feedback was appropriate.					
Answer keys were provided for exercises.					
Answer keys were provided for tests.					

Additional comments:

Appendix F: Instructional designer's evaluation form

Physics (Electrical circuits)

<table>
<tr><td>Instructional Designer's Name</td><td colspan="2">Location</td><td>Date</td></tr>
<tr><td colspan="4">Delivery of Content
To determine whether the instructional objectives are well-defined and feasible</td></tr>
<tr><td>Evaluation Points</td><td>Yes</td><td colspan="2">Needs Improvement
Comments</td></tr>
<tr><td>Are the learning objectives clearly stated?</td><td></td><td colspan="2"></td></tr>
<tr><td>Are the learning objectives measurable?</td><td></td><td colspan="2"></td></tr>
<tr><td>Are the learning objectives feasible?</td><td></td><td colspan="2"></td></tr>
<tr><td>Is the content accurate?</td><td></td><td colspan="2"></td></tr>
<tr><td>Is the content presented in a language appropriate for the learners?</td><td></td><td colspan="2"></td></tr>
<tr><td>Is the material grammatically correct and free from errors?</td><td></td><td colspan="2"></td></tr>
<tr><td>Is the language appropriate and easy to follow</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="4">Delivery System
Method and mode of presenting the material
(Appropriate and effective for achieving the learning outcome)</td></tr>
</table>

Evaluation Points	**Yes**	**Needs Improvement** **Comments**
Is the delivery system effective for achieving the learning outcomes?		
Use of Instructional Strategies For increasing student's knowledge and use of the system [Appropriate practice items]		
Evaluation Points	**Yes**	**Needs Improvement** **Comments**
Does the instruction effectively integrate practice for achieving the learning objectives?		
Are appropriate instructional strategies used for achieving learning objectives?		
Are graphics used appropriately?		
Are provisions made for effective feedback?		
Are there opportunities for interaction?		
Is instruction provided in a logical sequence?		
Is all content necessary for understanding the topic provided?		
Assessment Measures To evaluate performance outcomes		

Evaluation Points	**Yes**	**Needs Improvement Comments**
Are the assessment items well constructed?		
Do the assessment items correlate with the learning objectives?		
Do the assessment items evaluate the effectiveness of achieving the desired learning outcomes?		
Are assessment measures used for remediation?		

Additional comments:

Appendix G: Student's evaluation form

Physics lesson (Electrical circuits)

This evaluation form has been developed to understand your experience in completing the lessons on electrical circuits. Your inputs will help me in developing a learning environment as useful and effective as possible. In order to accomplish this, I require your suggestions and comments. Please fill up this evaluation form and e-mail it to me at kmarowolo@yahoo.co.uk. Your feedback will be greatly appreciated.

Student's name	Location	Date

Please select the appropriate response to each question			
Content		**Yes**	**No**
Were the course objectives/outcomes relevant to your needs?			
Was the content structured in a logical manner?			
Did the Introduction make it clear what you could expect from the instruction?			
Did you understand what you were supposed to learn?			
Did you find the graphics useful			
Did you notice any spelling and / or grammatical errors?			
Were there sufficient opportunities to practice what you were supposed to learn?			
Were the practice or learning activities relevant?			
Did you feel confident when answering the test questions?			
How satisfied are you with the skills acquired?	Fully satisfied	Moderately satisfied	Not satisfied
Were you satisfied with the quality of feedback from your learning activities/practice?	Fully satisfied	Moderately satisfied	Not satisfied
Was the instruction/tutorials interesting?	Very Interesting	Moderately Interesting	Not Interesting
Approximately how long did it take	One hour	Less than	More than

you to complete the entire course?		One hour	One hour
Presentation	Too much	Just Enough	Too little
Consider the amount of text that appears in the instructional material. Would you say there was	Too much	Just Enough	Too little
Consider the number of graphics used in the instructional material. Would you say there were	Too much	Just Enough	Too little

Learning Experience

Please provide brief comments on the following

Were there parts of the module you found particularly interesting? If so, would you list what they were and why you found them interesting? (e.g. the reading material, the practice exercises, tests etc)

Were there parts of the module that were presented in a manner you found particularly appealing to you as a learner? If so, would you list what they were and why you liked them? (e.g. introduction, graphics, layout, color coding, place for notes etc)

Were there parts of the module where you did not understand what you needed to do?

Suggestions For Improvement

Would you suggest improvements in any of the following:

Introduction
Amount of content
Presentation of content
Content Layout
Language used in the instructions
Amount of practice
Type of test
Help feature
Any other area

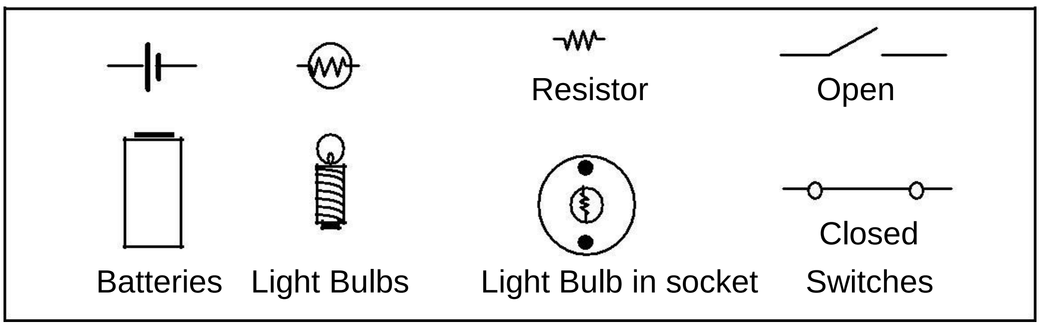
Appendix H: Electric circuits' test

Instructions

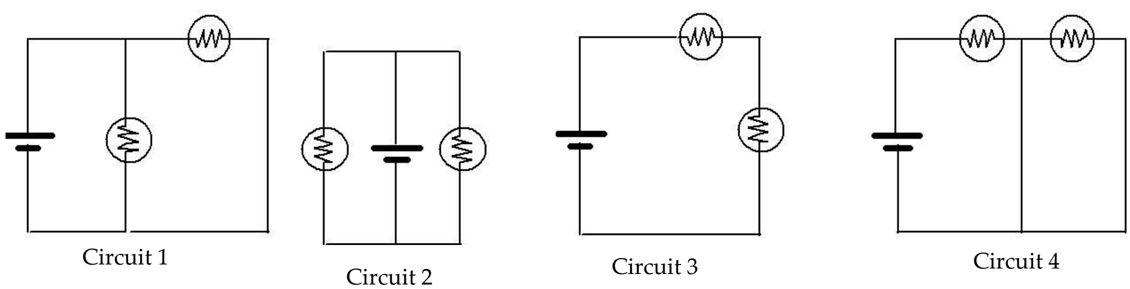
Wait until you are told to begin, then turn to the next page and begin working. Answer each question as accurately as you can. There is only one correct answer for each item. Feel free to use a calculator and scratch paper if you wish. You will have approximately half an hour to complete the test. If you finish early, check your work before handing in both the answer sheet and the test booklet.

Additional comments about the test

All light bulbs, resistors, and batteries should be considered identical unless you are told otherwise. The battery is to be assumed ideal, that is to say, the internal resistance of the battery is negligible. In addition, assume the wires have negligible resistance. Below is a key to the symbols used on this test. Study them carefully before you begin the test.



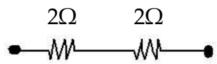
1. Which circuit or circuits below represent a circuit consisting of two light bulbs in parallel with a battery?



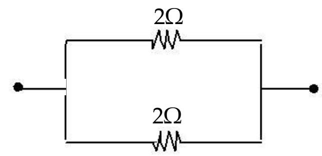
(A) Circuit 1
(B) Circuit 2
(C) Circuit 3
(D) Circuits 1 and 2
(E) Circuits 1, 2, and 4

2. Compare the resistance of branch 1 with that of branch 2. A branch is a section of a circuit. The resistance of branch 1 is _____ branch 2.

   (A) Four times
   (B) Double
   (C) The same as
   (D) Half
   (E) One quarter (1/4)



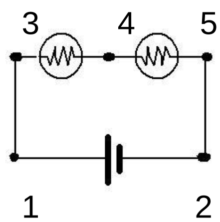
Branch 1



Branch 2

3. Rank the potential difference between points 1 and 2, points 3 and 4, and points 4 and 5 in the circuit shown below from HIGHEST to LOWEST.

   (A) 1 and 2; 3 and 4; 4 and 5
   (B) 1 and 2; 4 and 5; 3 and 4
   (C) 3 and 4; 4 and 5; 1 and 2
   (D) 3 and 4 = 4 and 5; 1 and 2
   (E) 1 and 2; 3 and 4 = 4 and 5



4. Compare the brightness of the bulb in circuit 1 with that in circuit 2. Which bulb is BRIGHTER?

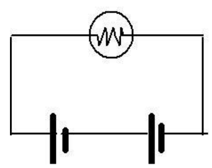
   (A) Bulb in circuit 1 because two batteries in series provide less voltage

   (B) Bulb in circuit 1 because two batteries in series provide more voltage

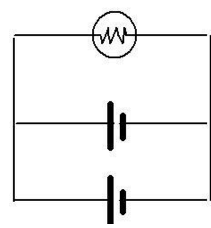
   (C) Bulb in circuit 2 because two batteries in parallel provide less voltage

   (D) Bulb in circuit 2 because two batteries in parallel provide more voltage

   (E) Neither, they are the same



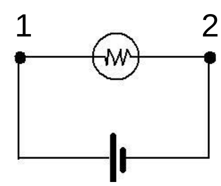
Circuit 1



Circuit 2

5. Compare the current at point 1 with the current at point 2. Which point has the LARGER current?

   (A) Point 1



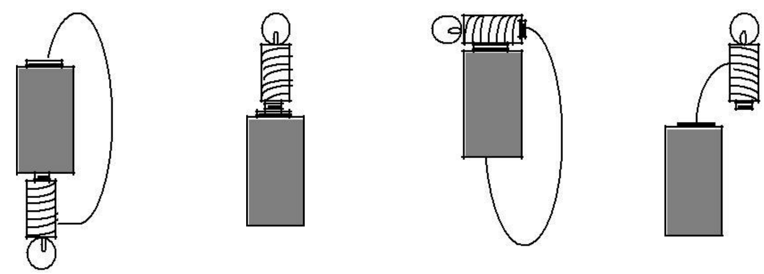
(B) Point 2

(C) Neither, they are the same. Current travels in one direction around the circuit.

(D) Neither, they are the same. Currents travel in two directions around the circuit.

6. Which circuit or circuits will light the bulb?

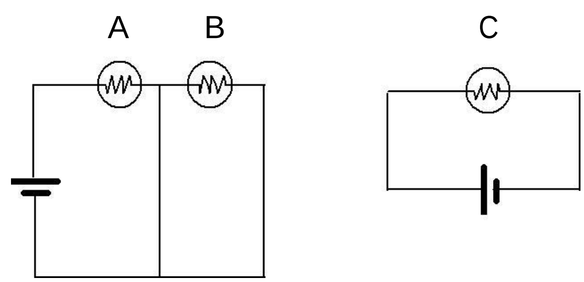
(A) Circuit 1
(B) Circuit 2
(C) Circuit 3
(D) Circuits 1 and 3
(E) Circuits 1, 3, and 4



Circuit 1 Circuit 2 Circuit 3 Circuit 4

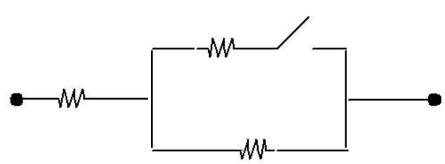
7. Compare the brightness of bulbs A, B, and C in these circuits. Which bulb or bulbs are the BRIGHTEST?

(A) A
(B) B
(C) C
(D) A = B
(E) A = C



8. How does the resistance between the endpoints change when the switch is closed?

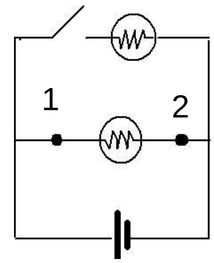
(A) Increases by R
(B) Increases by R/2
(C) Stays the same
(D) Decreases by R/2
(E) Decreases by R



9. What happens to the potential difference between points 1 and 2 when the switch is closed?

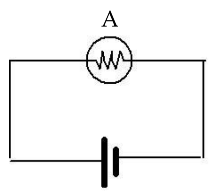
(A) Quadruples (4 times)
(B) Doubles

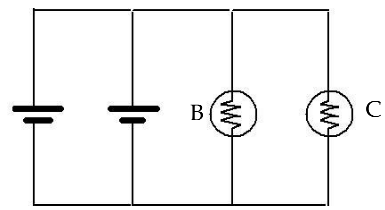
(C) Stays the same
(D) Reduces by half
(E) Reduces by one quarter (1/4)



10. Compare the brightness of bulb A with bulb B. Bulb A is _____ bright as Bulb B.

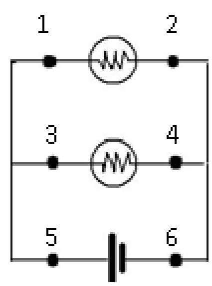
(A) Four times as
(B) Twice as
(C) Equally
(D) Half as
(E) One fourth (1/4) as





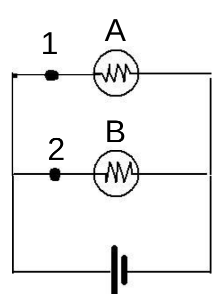
11. Rank the currents at points 1, 2, 3, 4, 5, and 6 from HIGHEST to LOWEST.

(A) 5, 3, 1, 2, 4, 6
(B) 5, 3, 1, 4, 2, 6
(C) 5 = 6, 3 = 4, 1 = 2
(D) 5 = 6, 1 = 2 = 3 = 4
(E) 1 = 2 = 3 = 4 = 5 = 6



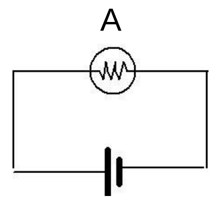
13. What happens to the brightness of bulbs A and B when a wire is connected between points 1 and 2?

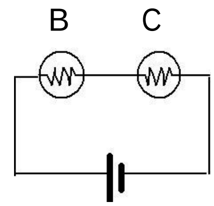
(A) Both increase
(B) Both decrease
(C) They stay the same
(D) A becomes brighter than B
(E) Neither bulb will light



14. Compare the brightness of bulb A with bulb B. Bulb A is _____ bright as bulb B.

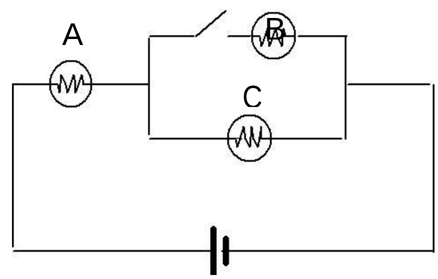
(A) Four times as
(B) Twice as
(C) Equally
(D) Half as
(E) One fourth (1/4) as





15. What happens to the brightness of bulbs A and B when the switch is closed?

(A) A stays the same, B dims
(B) A brighter, B dims
(C) A and B increase
(D) A and B decrease
(E) A and B remain the same



16. Two resistors R_1 and R_2 are connected in parallel. If R_2 is greater than R_1, what will the effective resistance be? The effective resistance will be

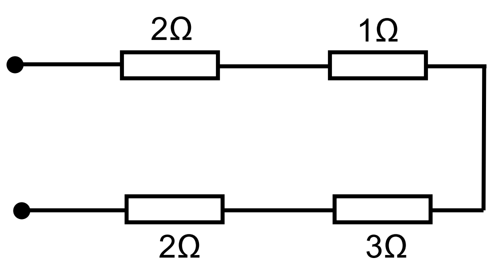
A. greater than R_1

B. the difference of R_2 and R_1

C. less than R_1

D. the sum of R_1 and R_2

17. What is the effective resistance in the circuit below?



A. 1.88Ω

B. 1Ω

C. 8Ω

D. 10Ω

18. Which of the following is constant (remains the same) in series circuits?

A. Voltage

B. Resistance

C. Current

D. All are constant

19. Which of the following is constant (remains the same) in parallel circuits?

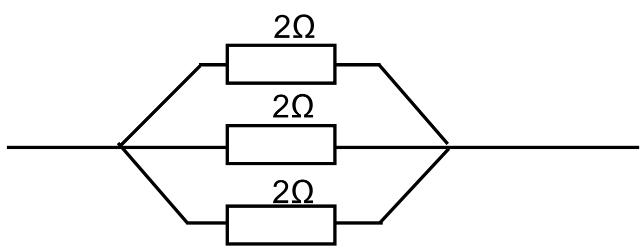
A. Voltage

B. Resistance

C. Current

D. All are constant

20. Calculate the effective resistance in the arrangement below.



D. 6Ω

C. 8Ω

B. 0.67

A. 1.33

Appendix I: Results of the one-to-one Formative Evaluation - Student's Evaluation Form on the ECT

Student's name	Location	Date
Please select the appropriate response to each question		
Content	**Yes**	**No**
Were the course objectives/outcomes relevant to your needs?	15	Nil
Was the content structured in a logical manner?	14	1
Did the Introduction make it clear what you could expect from the instruction?	15	Nil
Did you understand what you were supposed to learn?	15	Nil
Did you find the graphics useful	15	Nil
Did you notice any spelling and / or grammatical errors?	1	14
Were there sufficient opportunities to practice what you were supposed to learn?	14	1
Were the practice or learning activities relevant?	15	Nil

Did you feel confident when answering the test questions?		14	1
How satisfied are you with the skills acquired?	Fully satisfied (10)	Moderately satisfied (4)	Not satisfied (1)
Were you satisfied with the quality of feedback from your learning activities/practice?	Fully satisfied (6)	Moderately satisfied (8)	Not satisfied (1)
Was the instruction/tutorials interesting?	Very Interesting (11)	Moderately Interesting (4)	Not Interesting (Nil)
Approximately how long did it take you to complete the entire course?	One hour (5)	Less than One hour (4)	More than One hour (6)
Presentation	Too much	Just Enough	Too little
Consider the amount of text that appears in the instructional material. Would you say there was	Too much (Nil)	Just Enough (15)	Too little (Nil)
Consider the number of graphics used in the instructional material. Would you say there were	Too much (1)	Just Enough (12)	Too little (2)
Learning Experience **Please provide brief comments on the following**			
Question: Were there parts of the module you found particularly interesting? If so, would you list what they were and why you found them interesting? (e.g. the reading material, the practice exercises, tests etc).			

Student 1 (A.F): The tutorial was okay, I don't think I really found an interesting part of the tutorial. But the tutorial was presentable enough. Student 2 (Y.O.Z): I found the sound interesting. Student 3 (F.O): The reading material opened my brain more on things of physics especially in cells, resistance and voltage. Student 4 (I.O): Part 1 – the materials provided are enough. Student 5 (S.H): The part I found interesting is the practical part I found so interesting in the material. Student 6 (E.J): The question and answer section. The reading material. The reading material is interesting because they are new things that I have not seeing before. Student 7 (R.R): The tutorial was very interesting, because I was able to know how to answer in computer system when the external exam comes. Student 8 (I.O.S): The tutorial was very interesting to me because I was able to reverse back my memory about everything in electric circuit and I also learned much about it. Student 9 (J.S): The construction part because it makes it look real like real practical and it enlighten me more. Student 10 (A.B): The practice exercises is very interesting because I am able to recall all what I have been taught right from JSS to SSS class. Student 11 (B.D): Yes, because it enlightened me on things which I have forgotten. Student 12 (A.A.M): The practice exercises was very interesting because it gives you a room to know if you grab what you just learned. Student 13 (A.O.I): It tell us more about circuit and Ohm's law. Student 14 (N.C): It will tell us more about circuits and how to connect a wire from a battery to a bulb because wrong connection may lead to explosion I experience when building circuits. Student 15 (M.J.O): The practice exercises was interesting. It show me my correction. Student 16 (A.J): I found it interesting because what I have not been taught before I knew it today especially the question and answer.
Question: Were there parts of the module that were presented in a manner you found particularly appealing to you as a learner? If so,

would you list what they were and why you liked them? (e.g. introduction, graphics, layout, color coding, place for notes etc).

Student 1 (A.F): The parts of tutorial would obviously be appealing to learners, and it was also appealing to me being a learner. I like the place for notes. Even though they were short notes, it brought out exactly the information needed to know about the topic.

Student 2 (Y. O. Z): Yes, it was appealing as a learner. The notes were straightforward and understandable.

Student 3 (F.O): The graphics, colour coding, were good. I liked it because I am normally attracted to colours.

Student 4 (I.O): Yes, the graphics make me understand what they were talking about.

Student 5 (S.H): I found the graphics and the layout so easy.

Student 6 (E.J): I found the graphics appealing.

Student 7 (R.R): I really like the tutorial, because there introduction was very interesting to me.

Student 8 (I.O.S): I found it very appealing to me because it has given me an experience about the use of computers to write an exam particularly when I come across JAMB.

Student 9 (J.S): Examples and the formulas are not easily understandable to me.

Student 10 (A.B): The layout: The layout of what is to been done make it very interesting to me and make me like it very much.

Student 11 (B.D): No, they were alright and well designed.

Student 12 (A.A.M): The graphics look appealing because it makes you to recognize them when you see them anywhere.

Student 13 (A.O.I): The introduction was ok, the graphics, layout, colour coding they are very good. Student 14 (N.C): The introduction was ok and the layout was very wonderful it tell me more about electric circuits. Student 15 (M.J.O): The diagram was not clear shown and it does not have colour. Student 16 (A.J): I love all the answers provided because there is no grammatical error and I even understand all the English that it give me.
Question: Were there parts of the module where you did not understand what you needed to do? Student 1 (A.F): Of course, yes! Like where I needed to build a circuit. I didn't really understand or let me say, I didn't fully understand things I needed to do. Student 2 (Y.O.Z): Yes, like where I needed to build a circuit, and they were meant to tell us the amount of clicking to open it. Student 3 (F.O): Yes – I forgot to jot down some formulas, which made me fail the test. Student 4 (I.O): No Student 5 (S.H): I did not found anything difficult in the question. Student 6 (E.J): No Student 7 (R.R): At the first day, I was thinking that the tutorial may be difficult but at the end of the tutorial it was very interesting. Student 8 (I.O.S): At first I didn't find it easy to do, but later I begin to understand what to do. Student 9 (J.S): Yes, the test at the end and also the explanations. Student 10 (A.B): No, I understand every part of it. The use of resistors for

answering questions. Student 11 (B.D): Yes 'cause' we have not yet been taught. Student 12 (A.A.M): Yes, leading question No. 2: device an explanation. Student 13 (A.O.I): The construction of the circuit and the arrangement of parallel. Student 14 (N.C): Building of the circuit, how to solve the problem like resistance, voltage and current and so more. Student 15 (M.J.O): The arrangement of parallel and construction of the circuit. Student 16 (A.J): I understand all the tutorial
Suggestions For Improvement Would you suggest improvements in any of the following: Student 5 Yes there is improvement I also realized my mistakes; Student 6 the diagram in the practice was not really clear. I think improvement should be made on that because of the people with eye problem.
Introduction Student 3: It is ok; Student 5 so good as well; Student 7 yes; Student 8 yes; Student 11 yes; Student 13 the introduction was not enlighten enough; Student 14 the introduction was not enough for the student to know what they are about to do; Student 16 No.
Amount of content Student 3: It is ok; Student 4 quite enough; Student 5 very enough; Student 7 yes; Student 8 yes; Student 11 No because the questions were enough; Student 12 the amount should have examples for easy understanding; Student 16 No.
Presentation of content Student 3: It is ok; Student 4 very good; Student 5

very good; Student 7 yes; Student 8 yes; Student 11 No because it was well presented; Student 14 the content has to be presented in a very good way; Student 16 No.
Content Layout Student 2: Yes; Student 3: It is ok; Student 4 very good; Student 5 very clear; Student 7 yes; Student 8 yes; Student 11 Yes; Student 13 the content has be presented in a very good way;
Language used in the instructions Student 3: It is ok; Student 4 Interesting; Student 5 English; Student 7 yes; Student 8 yes; Student 11 No because it was our official language; Student 13 the language has to be in different way;
Amount of practice: Student 1 Yes; Student 2 Yes; Student 3: It is ok; Student 4 enough; Student 5 not enough; Student 7 yes; Student 8 yes; Student 11 yes; Student 12 enough examples was not given to practice well; Student 14 there should be enough question for the student; Student 15 the question should be more than ten;
Type of test: Student 3: It is ok; Student 4 Physics practical test in which we were taught; Student 7 yes; Student 8 yes; Student 10 the type of test must be well-explained to us for better understanding; Student 11 yes; Student 13 the type of test must have examples; Student 15 there should be opportunities to change answer;
Help feature: Student 1 Yes; student 2 Yes; Student 3: It is ok; Student 5 no problem; Student 7 yes; Student 8 yes; Student 11 yes; Student 14 there should be help feature in other to tell the student where and what to do if they have a problem to solve;
Any other area: Student 3: No; Student 7 yes; Student 8 yes; Student 9 not enough examples for the formulas to understand; Student 11 yes, the question graphics were not clear enough; I don’t like the part I have to speak out aloud but again I think it helps in some cases.

Appendix J: Data Analysis (Using SPSS)

1. ANOVA on the Self-explanation data by Treatment (n = 221; total number of self-explanations)

Table 21. Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound
Narration		10	7.80	1.989	.629	6.38	9.22
On-screen		10	3.60	1.578	.499	2.47	4.73
Sound cues		10	11.80	1.033	.327	11.06	12.54
Total		30	7.73	3.732	.681	6.34	9.13
Model	Fixed Effects			1.582	.289	7.14	8.33
	Random Effects				2.367	-2.45	17.92

Table 22. ANOVA

Self_Explanation

	Sum of Squares	df	Mean Square	F	Sig. of F
Between Groups	336.267	2	168.133	67.154	.000
Within Groups	67.600	27	2.504		
Total	403.867	29			

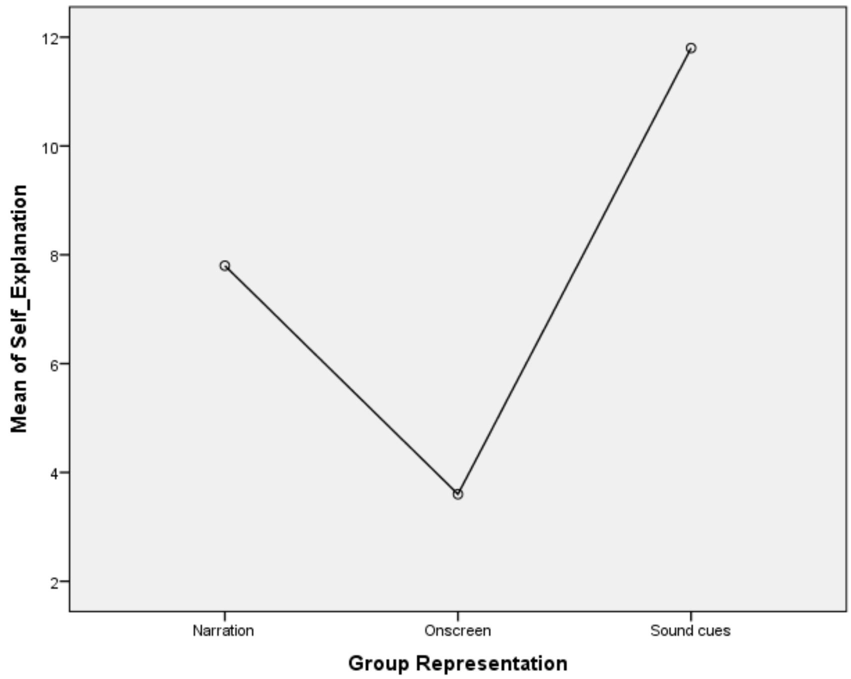


Figure 18. Mean plot of the self-explanation

Table 23. Multiple Comparisons

Dependent Variable: Self-Explanation

	(I) Group Representation	(J) Group Representation	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Tukey HSD	Narration	On-screen	4.200*	.708	.000	2.45	5.95
		Sound cues	-4.000*	.708	.000	-5.75	-2.25
	On-screen	Narration	-4.200*	.708	.000	-5.95	-2.45
		Sound cues	-8.200*	.708	.000	-9.95	-6.45
	Sound cues	Narration	4.000*	.708	.000	2.25	5.75
		On-screen	8.200*	.708	.000	6.45	9.95
Scheffe	Narration	On-screen	4.200*	.708	.000	2.37	6.03
		Sound cues	-4.000*	.708	.000	-5.83	-2.17
	On-screen	Narration	-4.200*	.708	.000	-6.03	-2.37
		Sound cues	-8.200*	.708	.000	-10.03	-6.37
	Sound cues	Narration	4.000*	.708	.000	2.17	5.83
		On-screen	8.200*	.708	.000	6.37	10.03

*. The mean difference is significant at the 0.05 level.

Table 24

ANOVA Tests on the self-explanation data

	(I) Experimental Conditions	(J) Experimental Conditions	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Narration	Onscreen	3.70*	.835	.000*	1.63	5.77*
		SoundCues	-3.90*	.835	.000*	-5.97	-1.83*
	Onscreen	Narration	-3.70*	.835	.000*	-5.77	-1.63*
		SoundCues	-7.60*	.835	.000*	-9.67	-5.53*
	SoundCues	Narration	3.90*	.835	.000*	1.83	5.97*
		Onscreen	7.60*	.835	.000*	5.53	9.67*
Scheffe	Narration	Onscreen	3.70*	.835	.001*	1.54	5.86*
		SoundCues	-3.90*	.835	.000*	-6.06	-1.74*
	Onscreen	Narration	-3.70*	.835	.001*	-5.86	-1.54*
		SoundCues	-7.60*	.835	.000*	-9.76	-5.44*
	SoundCues	Narration	3.90*	.835	.000*	1.74	6.06*
		Onscreen	7.60*	.835	.000*	5.44	9.76*

Table 25. Descriptive Statistics

	Group Representation	Mean	Std. Deviation	N
Pretest	Narration	27.65	8.124	17
	On-screen	22.06	4.351	17
	Sound cues	21.47	9.315	17
	Total	23.73	7.927	51
Posttest	Narration	35.88	10.931	17
	On-screen	32.94	11.464	17
	Sound cues	37.94	8.671	17
	Total	35.59	10.423	51
Delayed Posttest	Narration	25.29	12.927	17
	On-screen	25.59	12.733	17
	Sound cues	30.88	11.488	17
	Total	27.25	12.422	51

Table 26. Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig. of F
Pre_Pos_Del	Pillai's Trace	.523	25.745[b]	2.000	47.000	.000
	Wilks' Lambda	.477	25.745[b]	2.000	47.000	.000
	Hotelling's Trace	1.096	25.745[b]	2.000	47.000	.000
	Roy's Largest Root	1.096	25.745[b]	2.000	47.000	.000
Pre_Pos_Del * group	Pillai's Trace	.142	1.832	4.000	96.000	.129
	Wilks' Lambda	.859	1.861[b]	4.000	94.000	.124
	Hotelling's Trace	.164	1.887	4.000	92.000	.119
	Roy's Largest Root	.161	3.863[c]	2.000	48.000	.028

a. Design: Intercept + group
Within Subjects Design: Pre_Pos_Del
b. Exact statistic
c. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 28. Tests of Within-Subjects Contrasts

Source	Pre_Pos_Del	Type III Sum of Squares	df	Mean Square	F	Sig. of F
Pre_Pos_Del	Linear	317.647	1	317.647	3.197	.080
	Quadratic	3466.993	1	3466.993	39.062	.000
Pre_Pos_Del * group	Linear	588.235	2	294.118	2.960	.061
	Quadratic	47.712	2	23.856	.269	.765
Error(Pre_Pos_Del)	Linear	4769.118	48	99.357		
	Quadratic	4260.294	48	88.756		

Table 29. Tests of Between-Subjects Effects

Transformed Variable: Average

Table 27. Tests of Within-Subjects Effects

Source of Variation		Type III Sum of Squares	df	Mean Square	F	Sig. of F
Pre_Pos_Del	Sphericity Assumed	3784.641	2	1892.320	20.119	.000
	Greenhouse-Geisser	3784.641	1.851	2045.123	20.119	.000
	Huynh-Feldt	3784.641	2.000	1892.320	20.119	.000
	Lower-bound	3784.641	1.000	3784.641	20.119	.000
Pre_Pos_Del * group	Sphericity Assumed	635.948	4	158.987	1.690	.159
	Greenhouse-Geisser	635.948	3.701	171.825	1.690	.164
	Huynh-Feldt	635.948	4.000	158.987	1.690	.159
	Lower-bound	635.948	2.000	317.974	1.690	.195
Error(Pre_Pos_Del)	Sphericity Assumed	9029.412	96	94.056		
	Greenhouse-Geisser	9029.412	88.827	101.651		
	Huynh-Feldt	9029.412	96.000	94.056		
	Lower-bound	9029.412	48.000	188.113		

Source of Variation	Type III Sum of Squares	df	Mean Square	F	Sig. of F
Intercept	127400.163	1	127400.163	968.407	.000
group	310.131	2	155.065	1.179	.316
Error	6314.706	48	131.556		

Table 30. Parameter Estimates

Dependent Variable	Parameter	B	Std. Error	t	Sig. of F	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Pretest	Intercept	21.471	1.835	11.702	.000	17.781	25.160
	[group=1]	6.176	2.595	2.380	.021	.959	11.394
	[group=2]	.588	2.595	.227	.822	-4.629	5.805
	[group=3]	0[a]	.	.	.	.	.
Posttest	Intercept	37.941	2.529	15.004	.000	32.857	43.025
	[group=1]	-2.059	3.576	-.576	.567	-9.249	5.131
	[group=2]	-5.000	3.576	-1.398	.168	-12.190	2.190
	[group=3]	0[a]	.	.	.	.	.
Delayed Post	Intercept	30.882	3.007	10.269	.000	24.836	36.929
	[group=1]	-5.588	4.253	-1.314	.195	-14.139	2.963
	[group=2]	-5.294	4.253	-1.245	.219	-13.845	3.257
	[group=3]	0[a]	.	.	.	.	.

Table 31. Univariate Tests

Dependent Variable		Sum of Squares	df	Mean Square	F	Sig. of F
Pretest	Contrast	395.098	2	197.549	3.452	.040
	Error	2747.059	48	57.230		
Posttest	Contrast	214.706	2	107.353	.988	.380
	Error	5217.647	48	108.701		

DelayedPost	Contrast	336.275	2	168.137	1.094	.343
	Error	7379.412	48	153.738		

The F tests the effect of Group Representation. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Post Hoc Tests: Group Representation

Table 32. Multiple Comparisons

Post Hoc Tests	(I) Group Representation	(J) Group Representation	Mean Difference (I-J)	Std. Error	Sig. of F	95% Confidence Interval Lower Bound	Upper Bound
Tukey HSD	Narration	On-screen	2.75	2.271	.454	-2.75	8.24
		Sound cues	-.49	2.271	.975	-5.98	5.00
	On-screen	Narration	-2.75	2.271	.454	-8.24	2.75
		Sound cues	-3.24	2.271	.337	-8.73	2.26
	Sound cues	Narration	.49	2.271	.975	-5.00	5.98
		On-screen	3.24	2.271	.337	-2.26	8.73
Scheffe	Narration	On-screen	2.75	2.271	.487	-2.99	8.48
		Sound cues	-.49	2.271	.977	-6.23	5.25
	On-screen	Narration	-2.75	2.271	.487	-8.48	2.99
		Sound cues	-3.24	2.271	.370	-8.97	2.50
	Sound cues	Narration	.49	2.271	.977	-5.25	6.23
		On-screen	3.24	2.271	.370	-2.50	8.97

Based on observed means.
The error term is Mean Square(Error) = 43.852.

Profile Plots

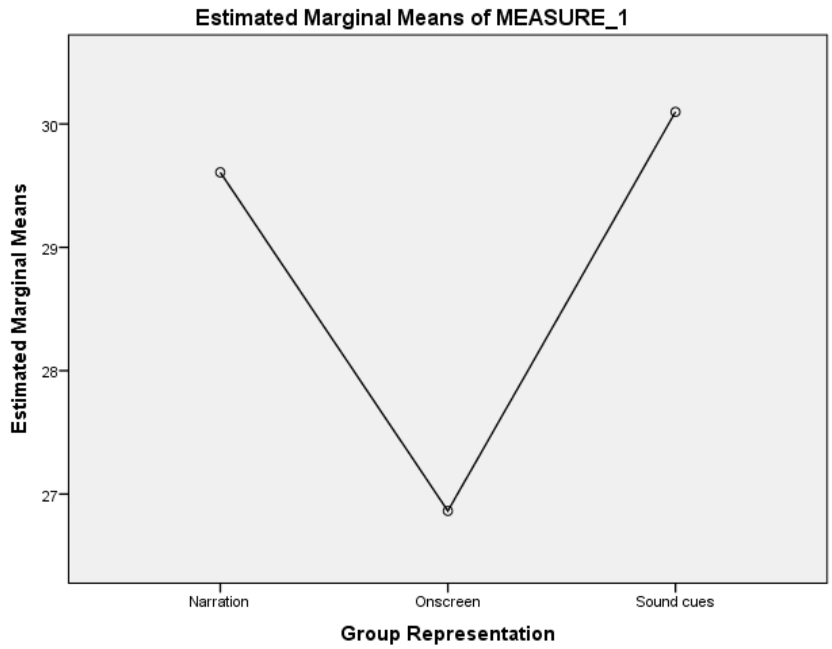


Figure 19. Estimated marginal means by treatment

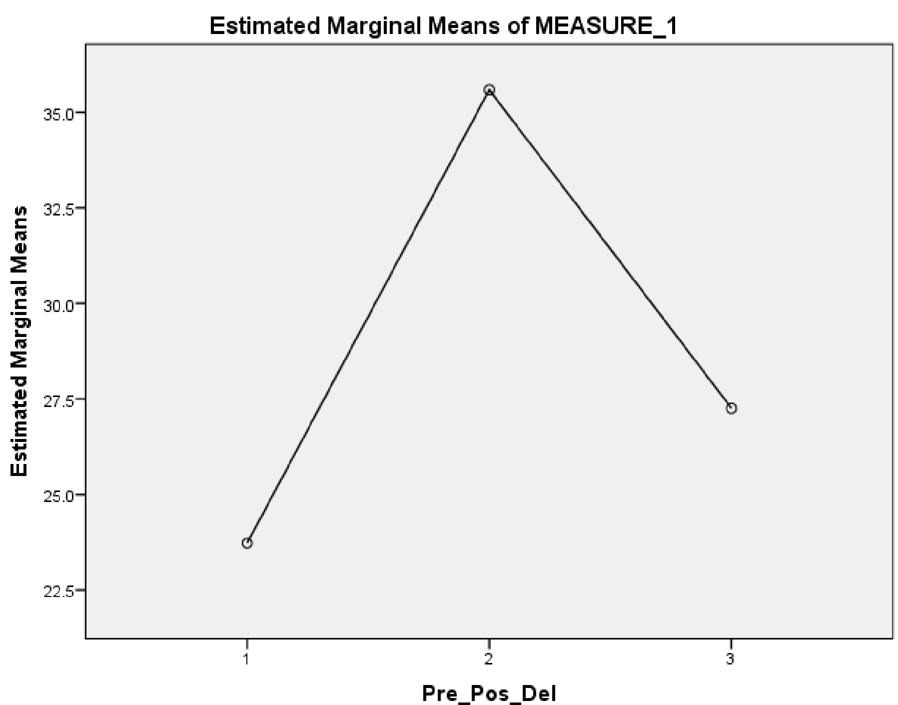


Figure 20. Estimated marginal means by occasions

3. Repeated Measures on the Posttest and Delayed Posttest by Treatment using the Pretest Score as Covariate (n = 51)

Table 34. Descriptive Statistics

	Group Representation	Mean	Std. Deviation	N
Posttest	Narration	35.88	10.931	17
	On-screen	32.94	11.464	17
	Sound cues	37.94	8.671	17
	Total	35.59	10.423	51
DelayedPost	Narration	25.29	12.927	17
	On-screen	25.59	12.733	17
	Sound cues	30.88	11.488	17
	Total	27.25	12.422	51

Table 35. Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig. of F
Pos_Del	Pillai's Trace	.010	.474[b]	1.000	47.000	.495
	Wilks' Lambda	.990	.474[b]	1.000	47.000	.495
	Hotelling's Trace	.010	.474[b]	1.000	47.000	.495
	Roy's Largest Root	.010	.474[b]	1.000	47.000	.495
Pos_Del * Pretest	Pillai's Trace	.005	.238[b]	1.000	47.000	.628
	Wilks' Lambda	.995	.238[b]	1.000	47.000	.628
	Hotelling's Trace	.005	.238[b]	1.000	47.000	.628
	Roy's Largest Root	.005	.238[b]	1.000	47.000	.628
Pos_Del * group	Pillai's Trace	.006	.139[b]	2.000	47.000	.870
	Wilks' Lambda	.994	.139[b]	2.000	47.000	.870

	Hotelling's Trace	.006	.139[b]	2.000	47.000	.870
	Roy's Largest Root	.006	.139[b]	2.000	47.000	.870

a. Design: Intercept + Pretest + group

Within Subjects Design: Pos_Del

b. Exact statistic

Table 36. Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig. of F
Pos_Del	Sphericity Assumed	54.955	1	54.955	.474	.495
	Greenhouse-Geisser	54.955	1.000	54.955	.474	.495
	Huynh-Feldt	54.955	1.000	54.955	.474	.495
	Lower-bound	54.955	1.000	54.955	.474	.495
Pos_Del * Pretest	Sphericity Assumed	27.642	1	27.642	.238	.628
	Greenhouse-Geisser	27.642	1.000	27.642	.238	.628
	Huynh-Feldt	27.642	1.000	27.642	.238	.628
	Lower-bound	27.642	1.000	27.642	.238	.628
Pos_Del * group	Sphericity Assumed	32.326	2	16.163	.139	.870
	Greenhouse-Geisser	32.326	2.000	16.163	.139	.870
	Huynh-Feldt	32.326	2.000	16.163	.139	.870
	Lower-bound	32.326	2.000	16.163	.139	.870
Error(Pos_Del)	Sphericity Assumed	5448.828	47	115.933		
	Greenhouse-Geisser	5448.828	47.000	115.933		
	Huynh-Feldt	5448.828	47.000	115.933		

	Lower-bound	5448.828	47.000	115.933

Table 37. Tests of Within-Subjects Contrasts

Source	Pos_Del	Type III Sum of Squares	df	Mean Square	F	Sig. of F
Pos_Del	Linear	54.955	1	54.955	.474	.495
Pos_Del * Pretest	Linear	27.642	1	27.642	.238	.628
Pos_Del * group	Linear	32.326	2	16.163	.139	.870
Error(Pos_Del)	Linear	5448.828	47	115.933		

Table 38. Tests of Between-Subjects Effects

Transformed Variable: Average

Source of Variation	Type III Sum of Squares	df	Mean Square	F	Sig. of F
Intercept	6589.753	1	6589.753	44.586	.000
Pretest	174.071	1	174.071	1.178	.283
group	567.992	2	283.996	1.922	.158
Error	6946.517	47	147.798		

Table 39. Parameter Estimates

Dependent Variable	Parameter	B	Std. Error	t	Sig. of F	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Posttest	Intercept	32.597	4.933	6.607	.000	22.672	42.521

	Pretest	.249	.198	1.259	.214	-.149	.647
	[group=1]	-3.596	3.758	-.957	.344	-11.157	3.965
	[group=2]	-5.146	3.556	-1.447	.155	-12.301	2.008
	[group=3]	0[a]	.	.	.	.	.
Delayed Post	Intercept	28.584	5.952	4.802	.000	16.609	40.558
	Pretest	.107	.239	.449	.656	-.373	.587
	[group=1]	-6.250	4.535	-1.378	.175	-15.372	2.873
	[group=2]	-5.357	4.291	-1.248	.218	-13.989	3.275
	[group=3]	0[a]	.	.	.	.	.

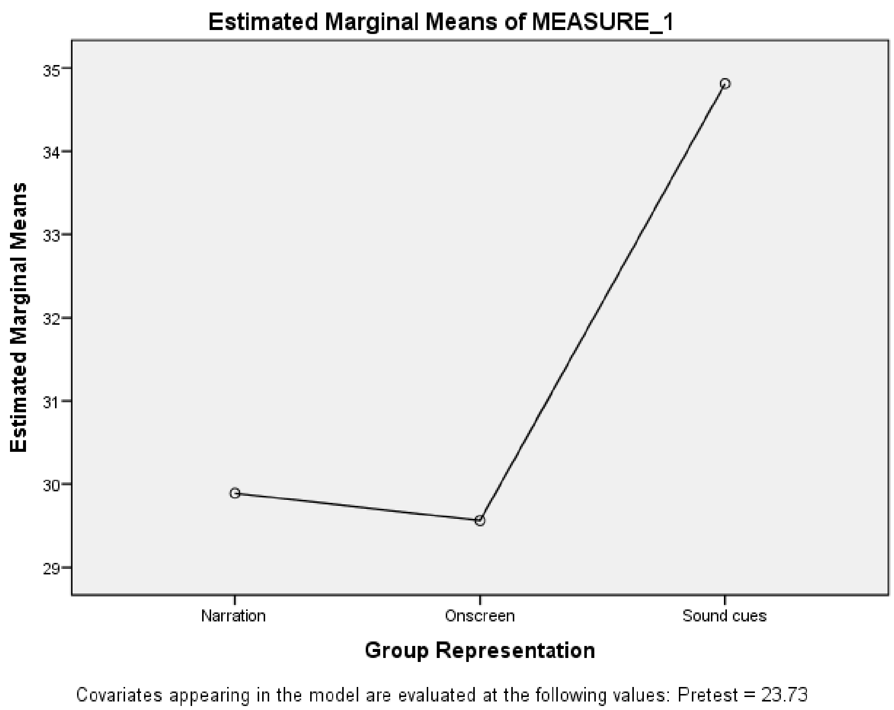


Figure 21. Estimated marginal means by occasion using the Pretest score as covariate

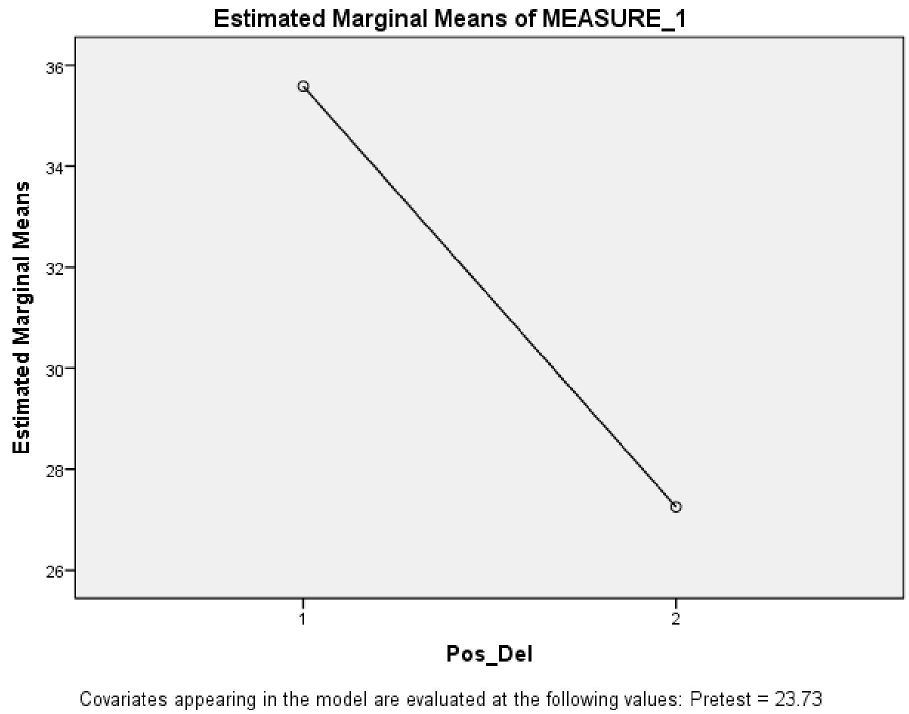
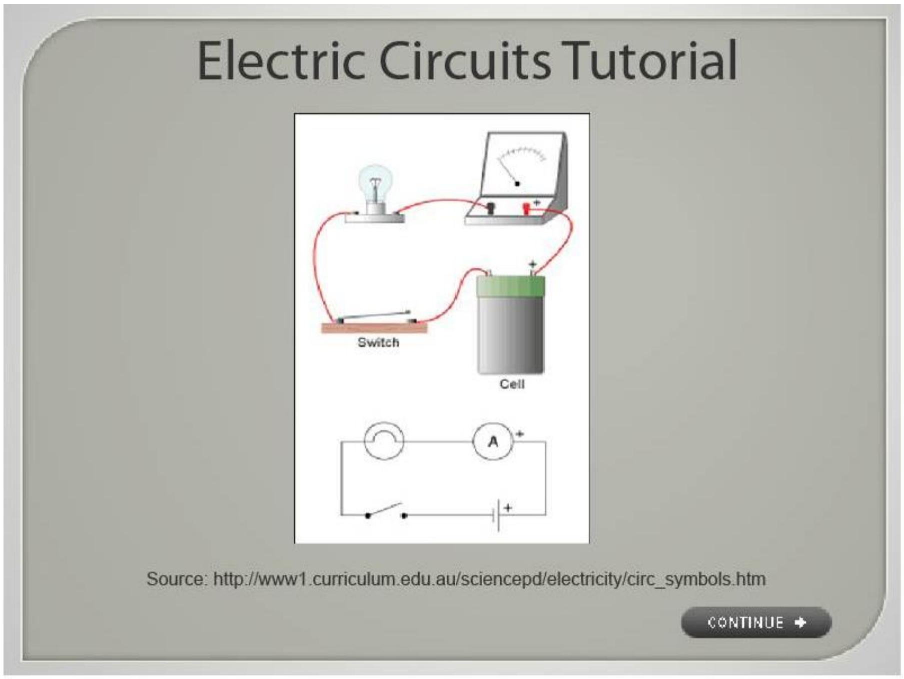
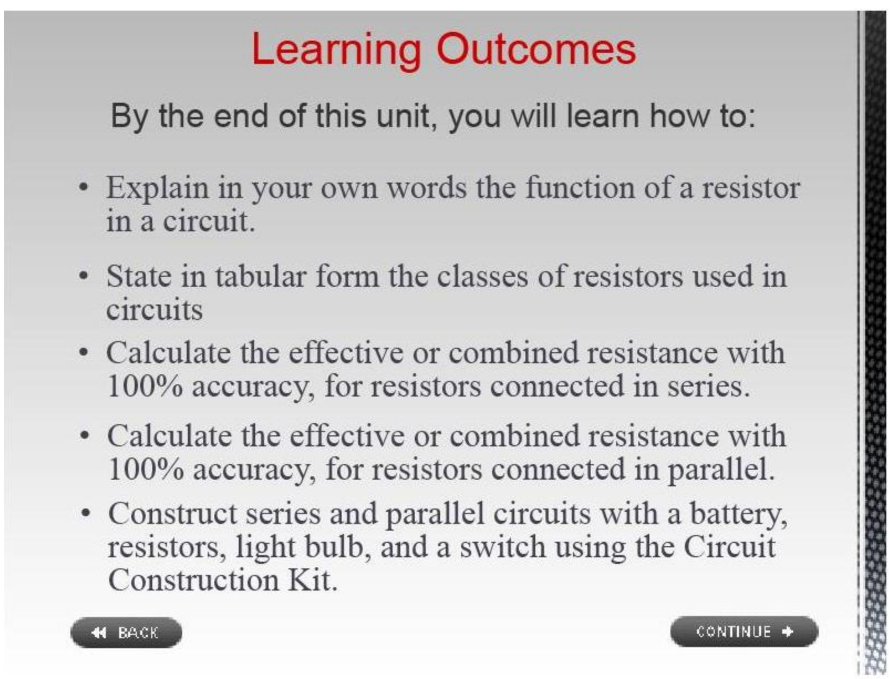


Figure 22. Estimated marginal means by treatment using the Pretests

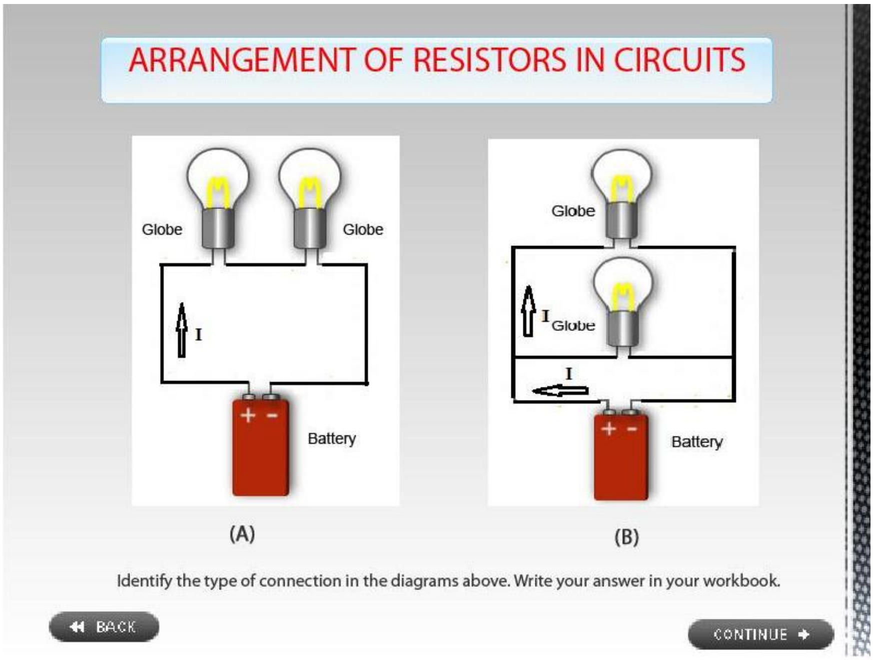
Appendix K: Electric Circuits' Tutorial (ECT)



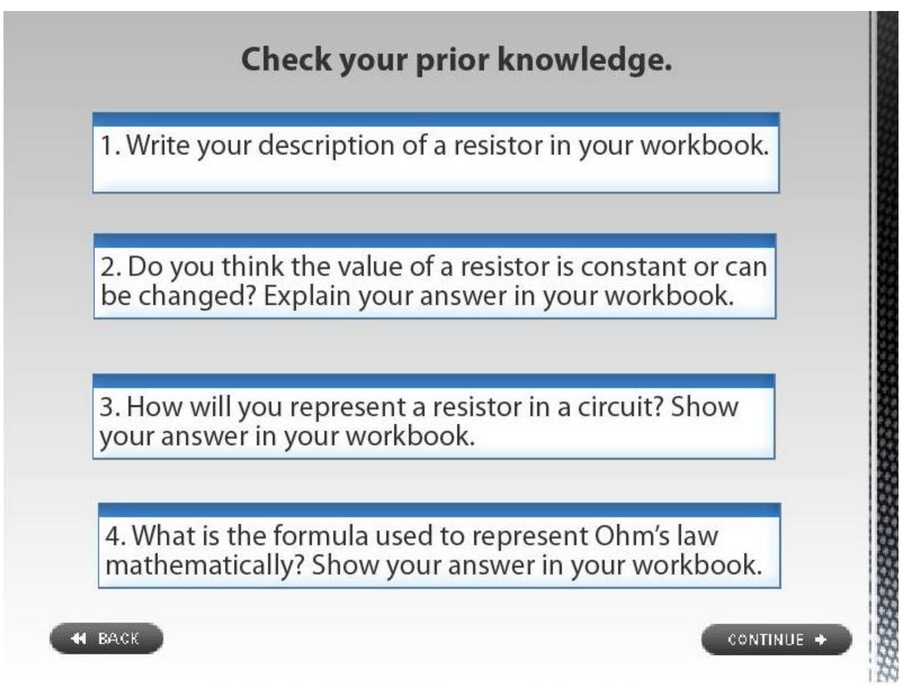
Electric Circuits' Tutorial (On-screen Text version) 1



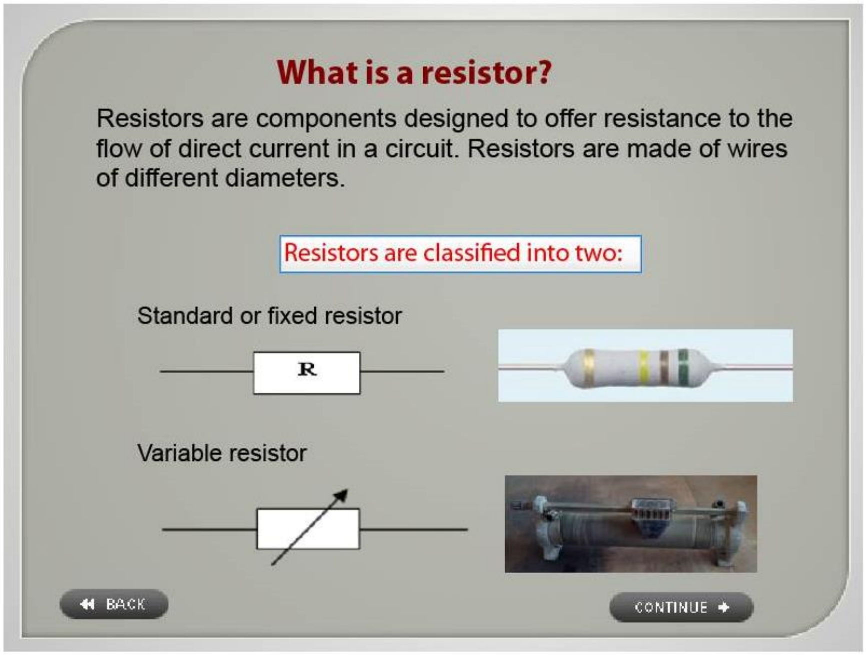
Electric Circuits' Tutorial (On-screen Text version) 2



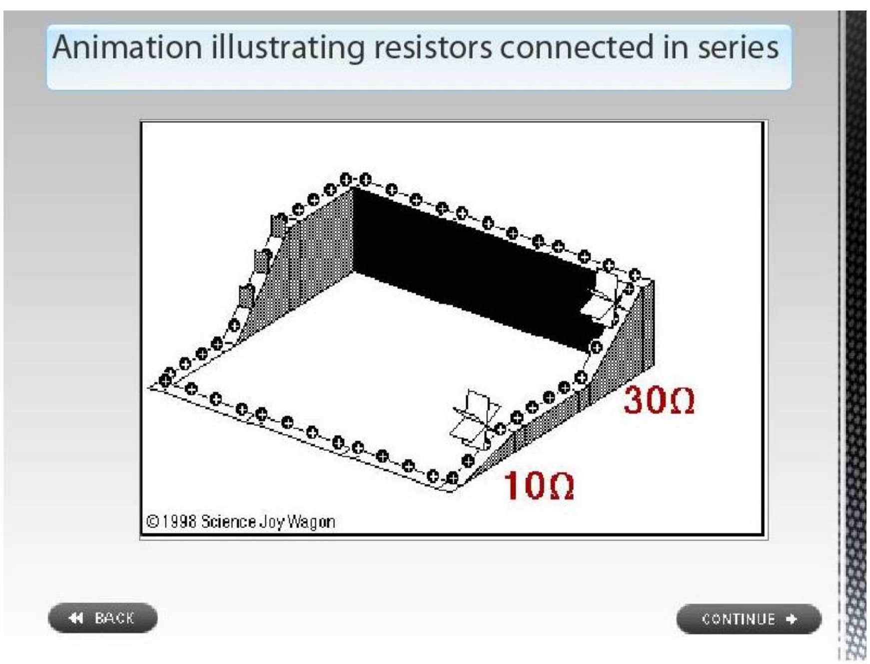
Electric Circuits' Tutorial (On-screen Text version) 3



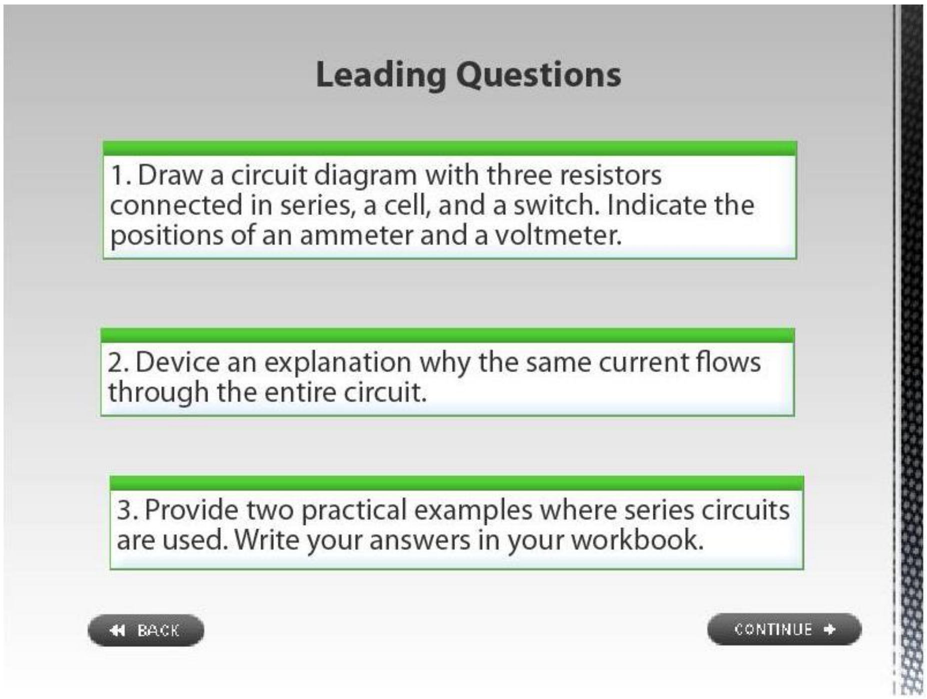
Electric Circuits' Tutorial (On-screen Text version) 4



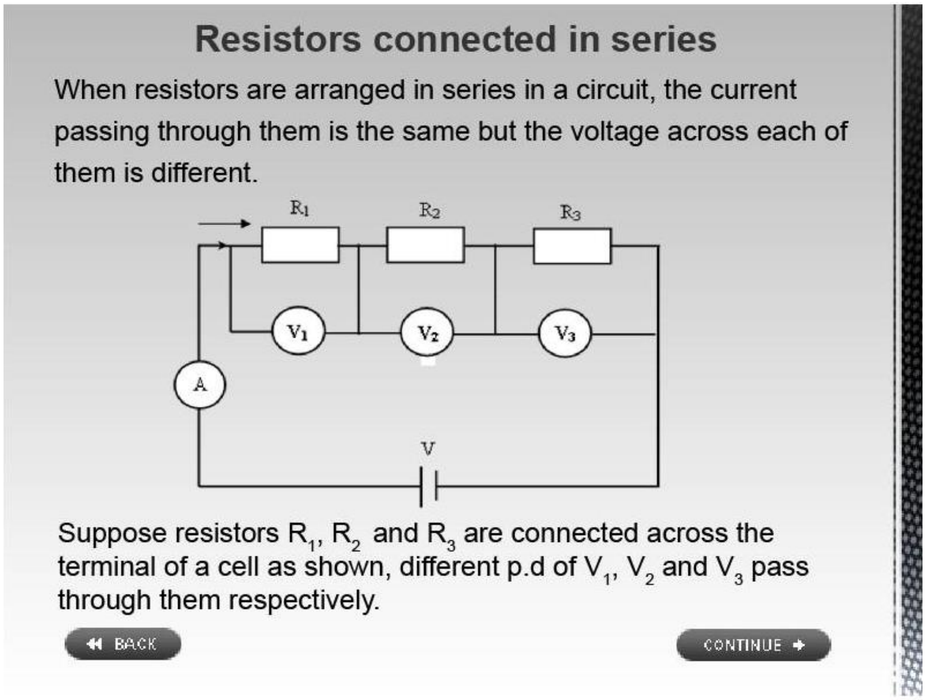
Electric Circuits' Tutorial (On-screen Text version) 5



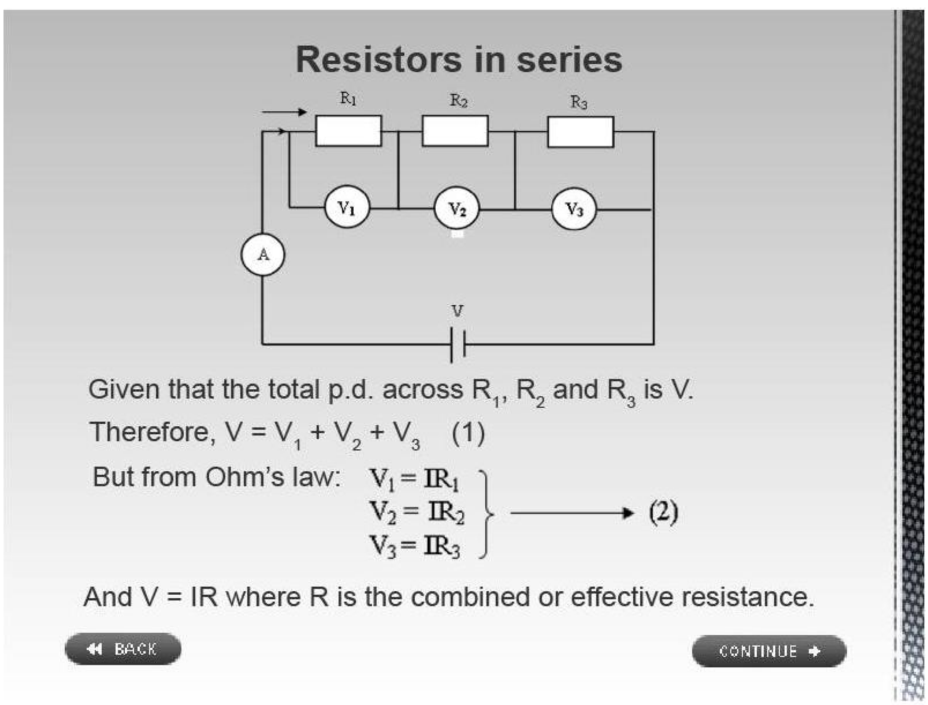
Electric Circuits' Tutorial (On-screen Text version) 6



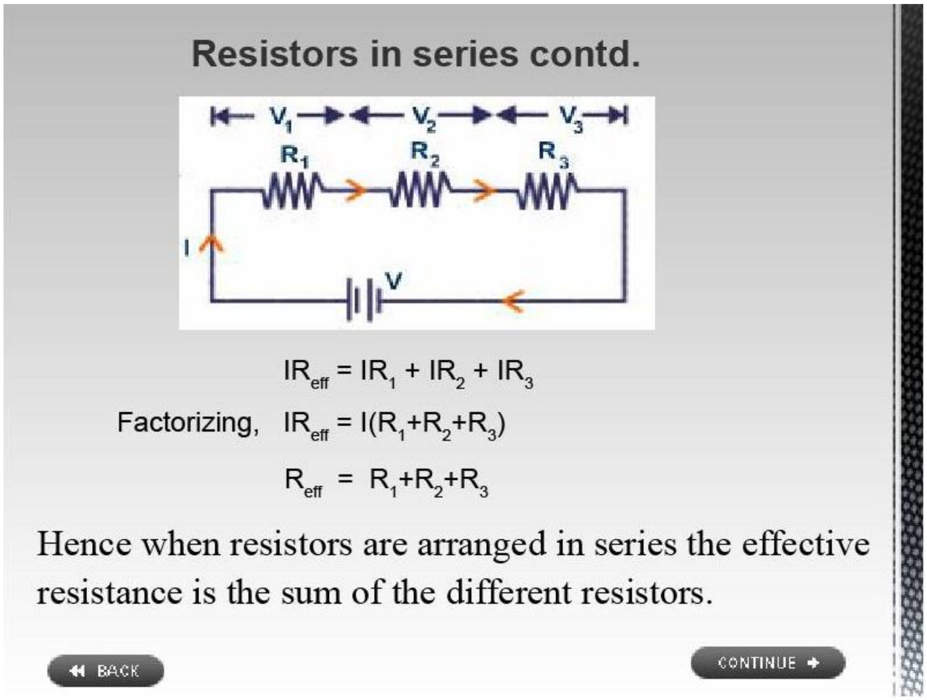
Electric Circuits' Tutorial (On-screen Text version) 7



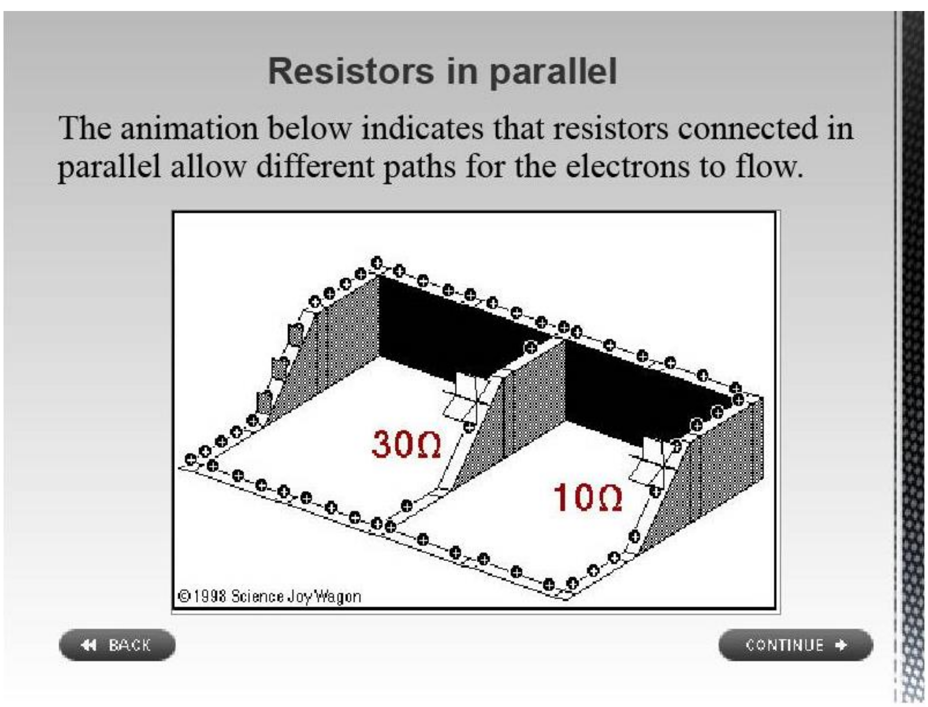
Electric Circuits' Tutorial (On-screen Text version) 8



Electric Circuits' Tutorial (On-screen Text version) 9

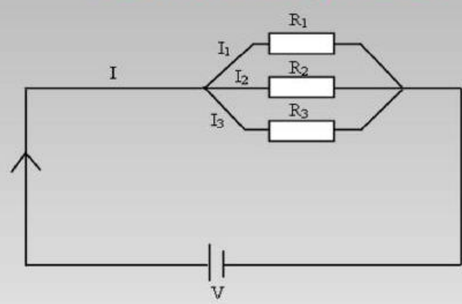


Electric Circuits' Tutorial (On-screen Text version) 10



Electric Circuits' Tutorial (On-screen Text version) 11

Resistors in parallel



Let I be the total current in the circuit

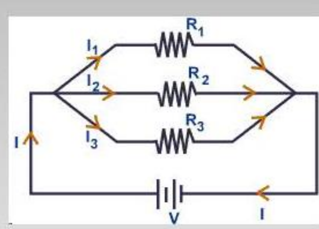
From ohm's law: $I = I_1 + I_2 + I_3 \longrightarrow (3)$

$$\left.\begin{aligned} I_1 &= \frac{V}{R_1} \\ I_2 &= \frac{V}{R_2} \\ I_3 &= \frac{V}{R_3} \end{aligned}\right\} \longrightarrow (4)$$

Therefore, $I = \dfrac{V}{R_{eff}}$

BACK CONTINUE

Resistors in parallel contd.

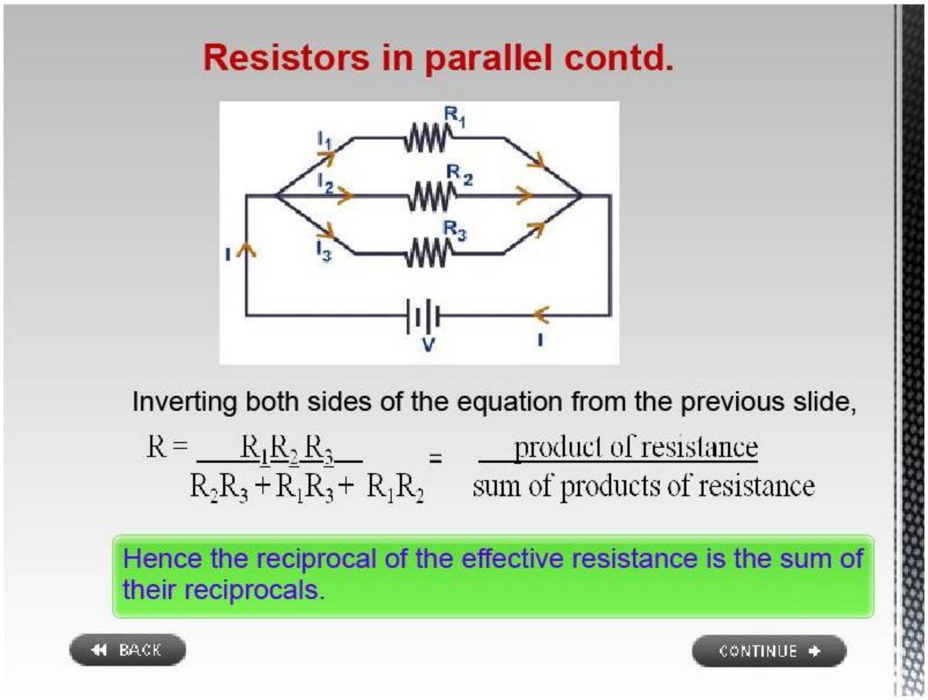


Substitute equation (4) in (3)

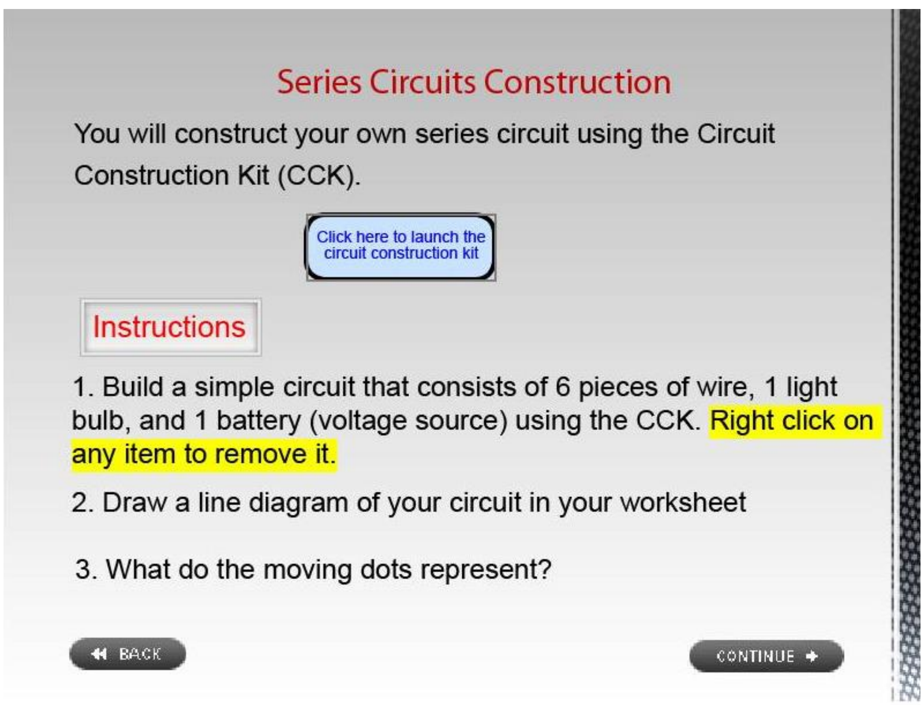
$$\frac{V}{R_{eff}} = V\left\{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right\}$$

$$\frac{1}{R_{eff}} = \left\{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right\}$$

BACK CONTINUE

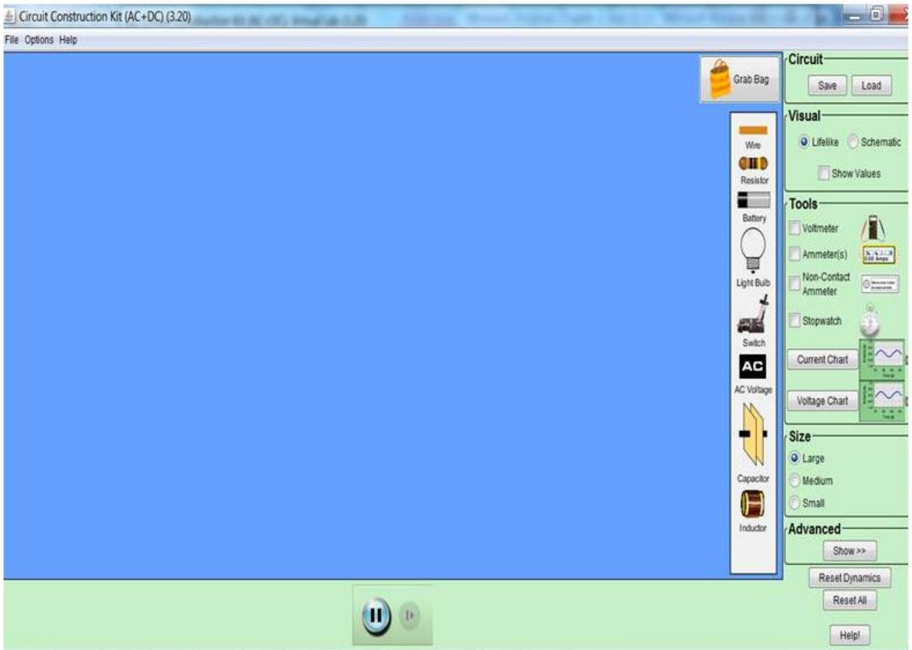


Electric Circuits' Tutorial (On-screen Text version) 14



Electric Circuits' Tutorial (On-screen Text version) 15

PhET CIRCUIT CONSTRUCTION KIT



Electric Circuits' Tutorial (On-screen Text version) 16

Series Circuits Construction continued

4. Now build the circuit shown in Fig. A below. You will have to click the check box next to ammeter to use it. Read and record the ammeter reading in your workbook.

Fig. A

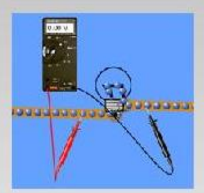


Fig. B

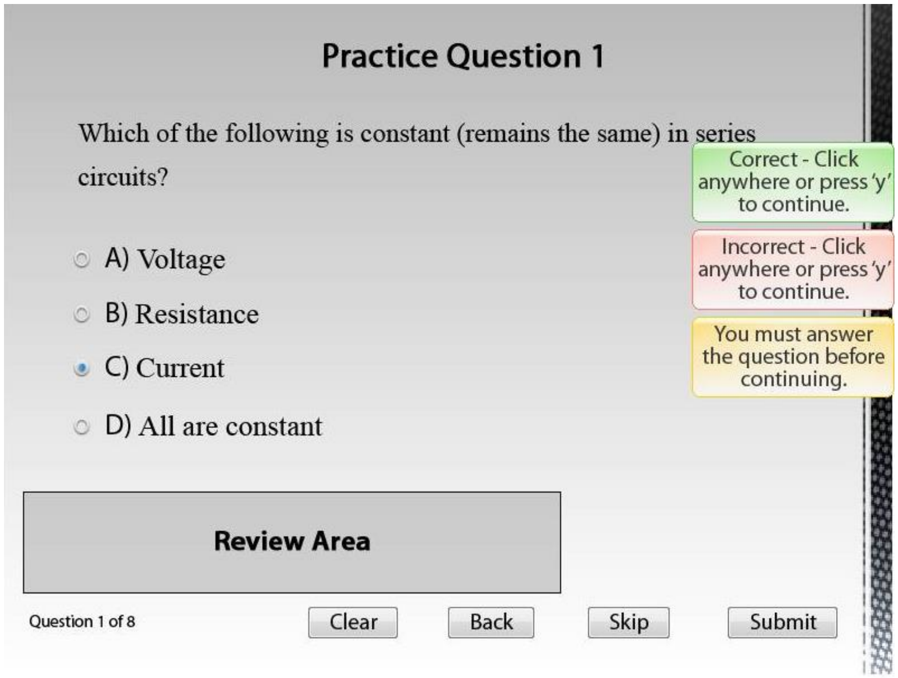
5. Tick the box for Voltmeter. Attach one of the Voltmeter's wires to each side of the light bulb as shown in figure (b) above. Read and record the value of the voltage in your workbook.

6. Build a circuit with 3 light bulbs that will light brightly with all 3 having the same brightness (same current, measures the same number of amps).

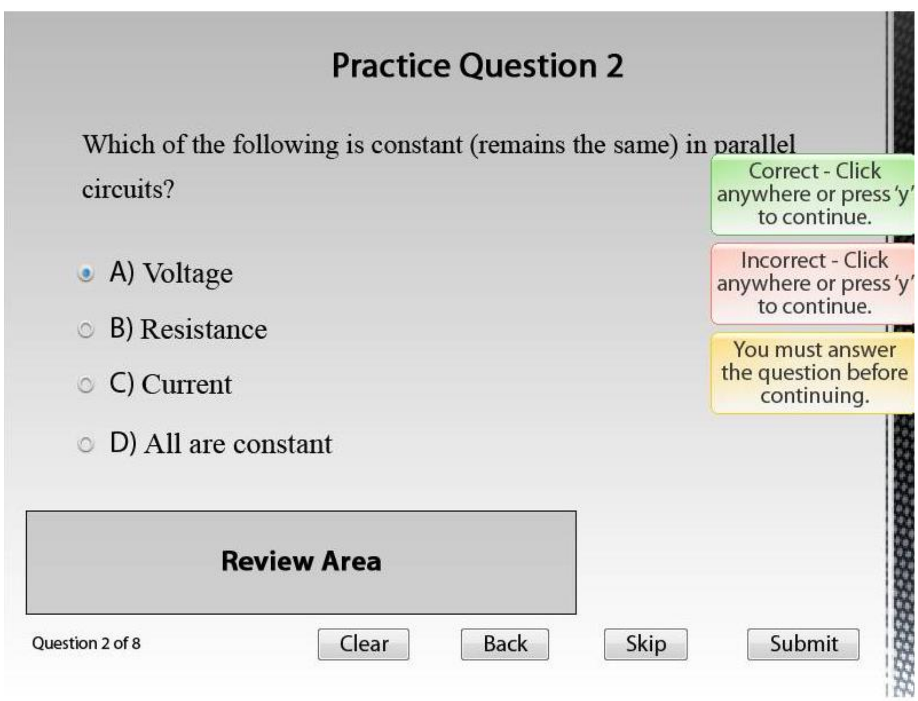
7. Now add another battery connected in series to your circuit in number 6 and observe the brightness. Record your observation in your workbook.

BACK CONTINUE

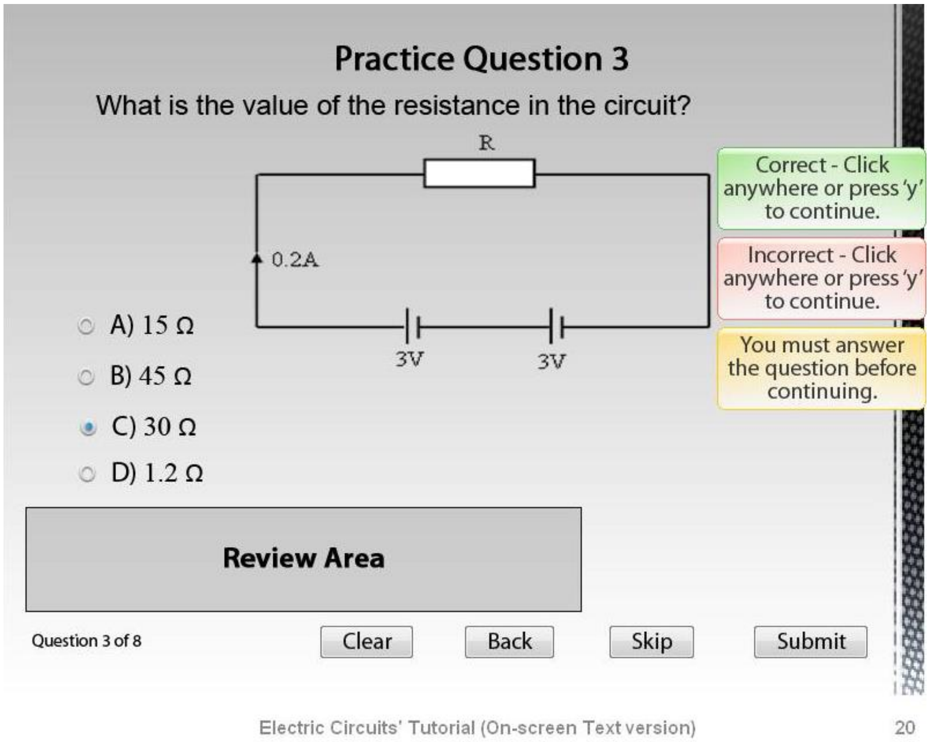
Electric Circuits' Tutorial (On-screen Text version) 17



Electric Circuits' Tutorial (On-screen Text version) 18



Electric Circuits' Tutorial (On-screen Text version) 19


Practice Question 3
What is the value of the resistance in the circuit?
R
0.2A
3V
3V
A) 15 Ω
B) 45 Ω
C) 30 Ω
D) 1.2 Ω
Correct - Click anywhere or press 'y' to continue.
Incorrect - Click anywhere or press 'y' to continue.
You must answer the question before continuing.
Review Area
Question 3 of 8
Clear
Back
Skip
Submit
Electric Circuits' Tutorial (On-screen Text version)
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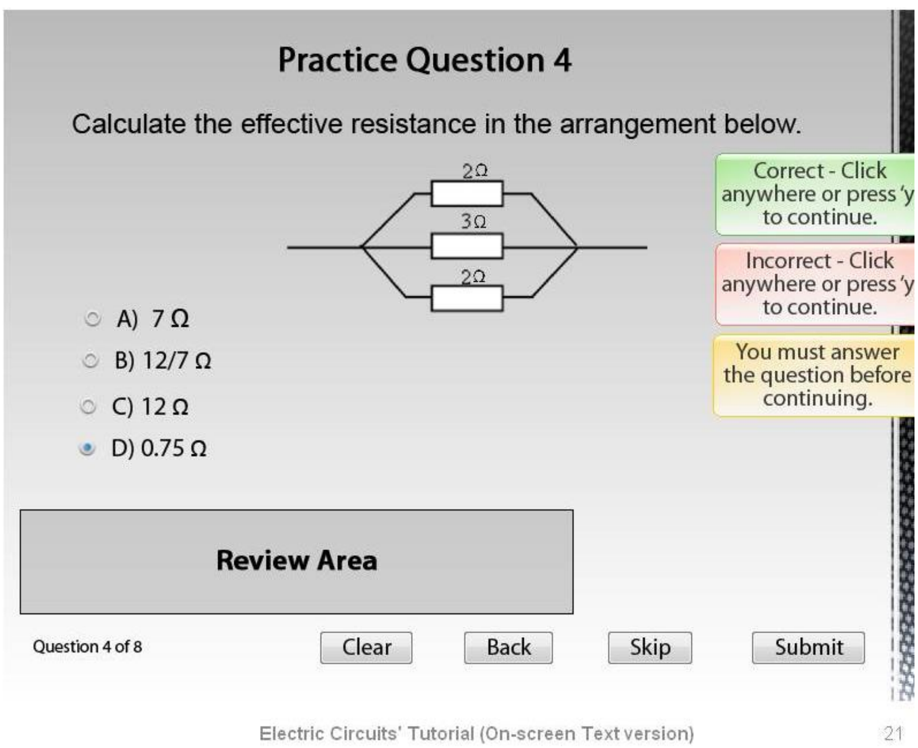
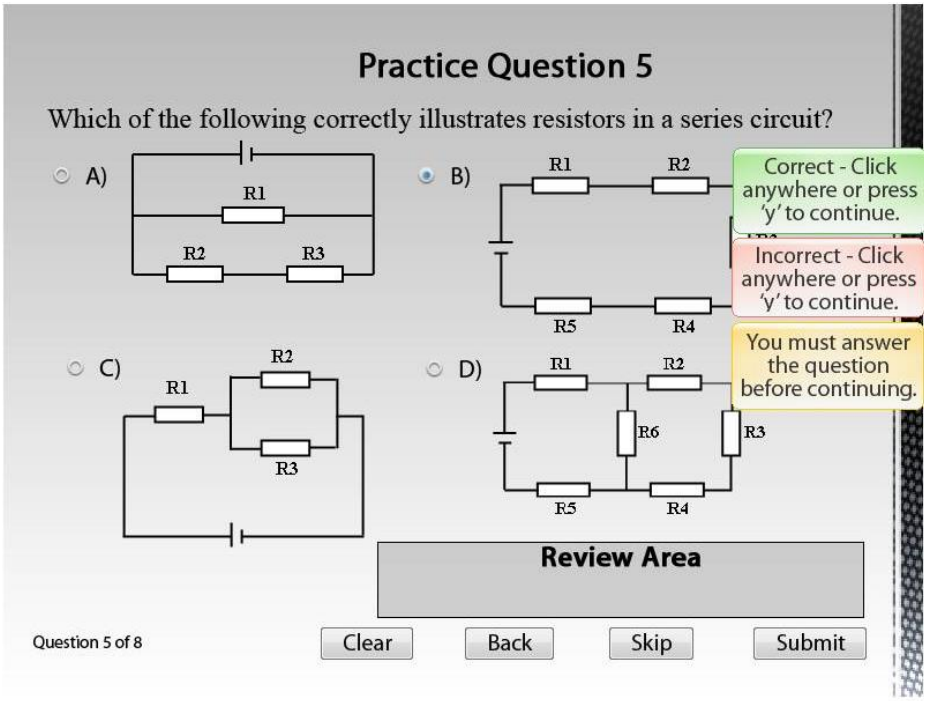
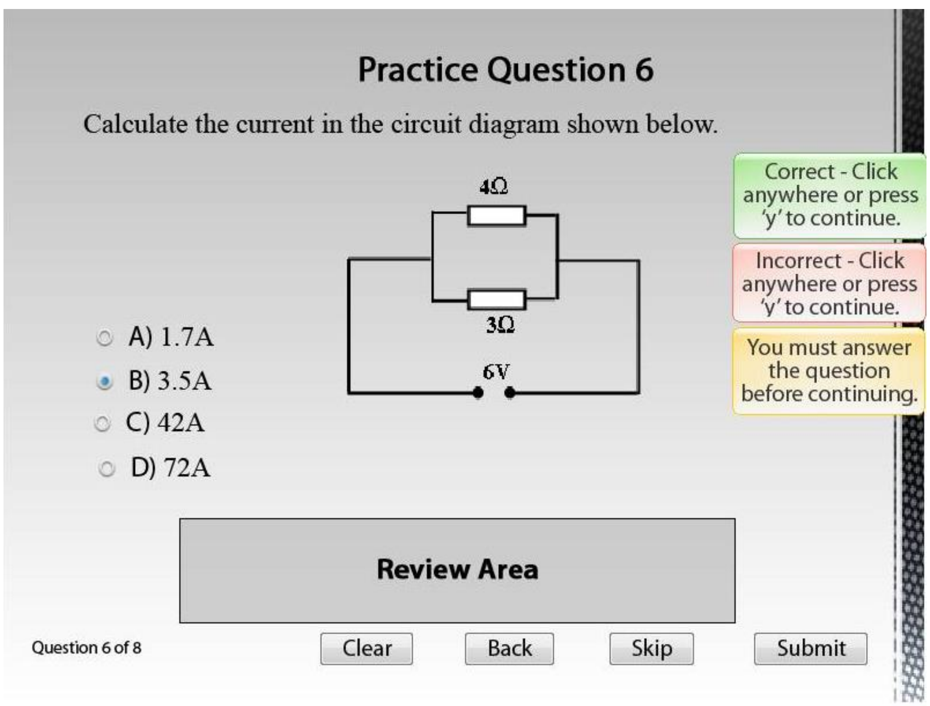

Practice Question 4
Calculate the effective resistance in the arrangement below.
2Ω
3Ω
2Ω
A) 7 Ω
B) 12/7 Ω
C) 12 Ω
D) 0.75 Ω
Correct - Click anywhere or press 'y to continue.
Incorrect - Click anywhere or press 'y to continue.
You must answer the question before continuing.
Review Area
Question 4 of 8
Clear
Back
Skip
Submit
Electric Circuits' Tutorial (On-screen Text version)
21



Electric Circuits' Tutorial (On-screen Text version) 22



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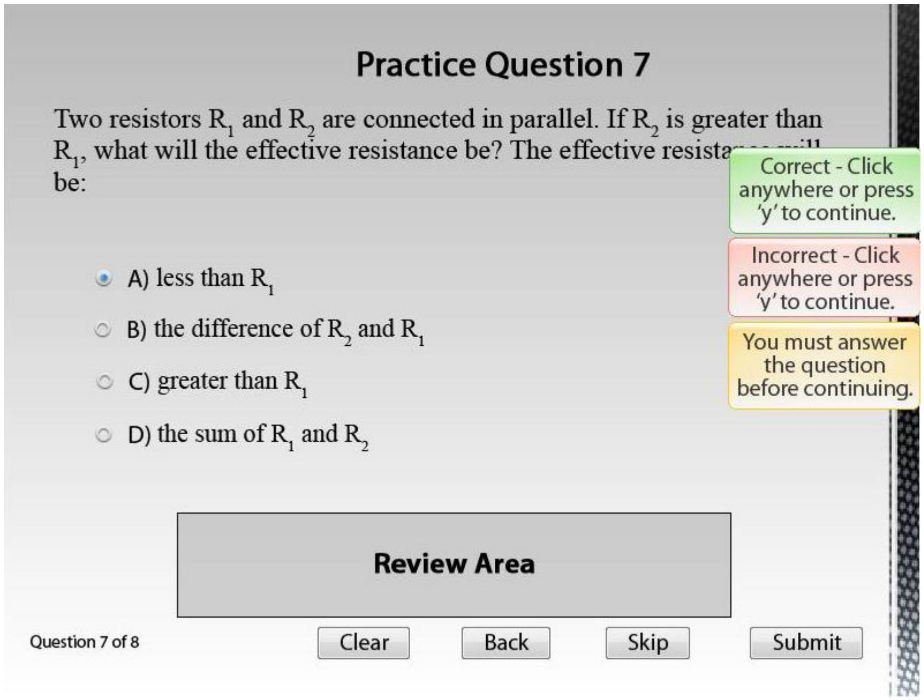

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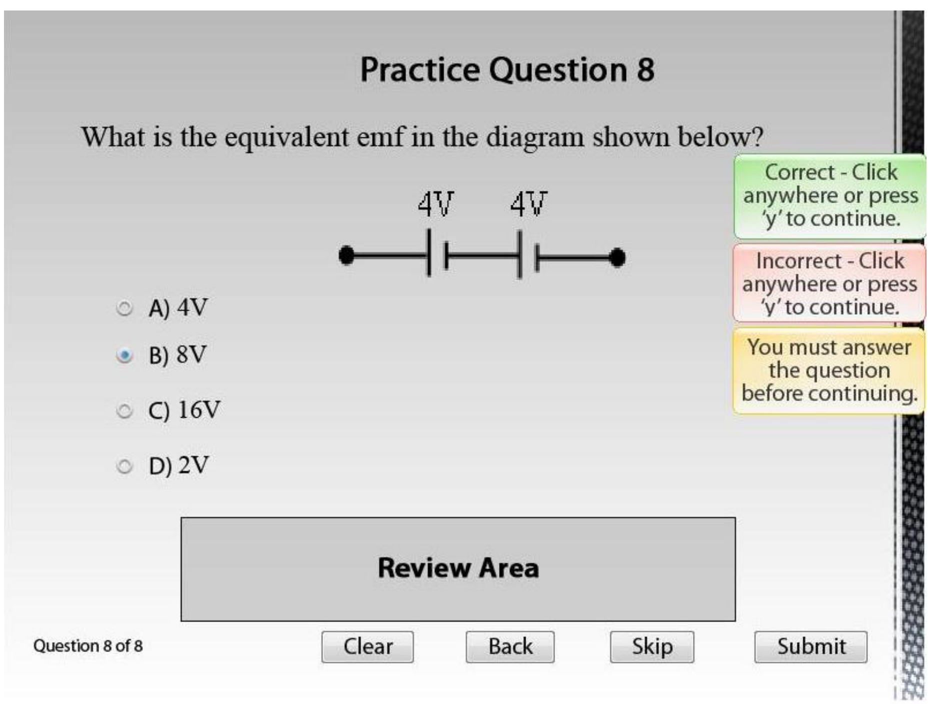

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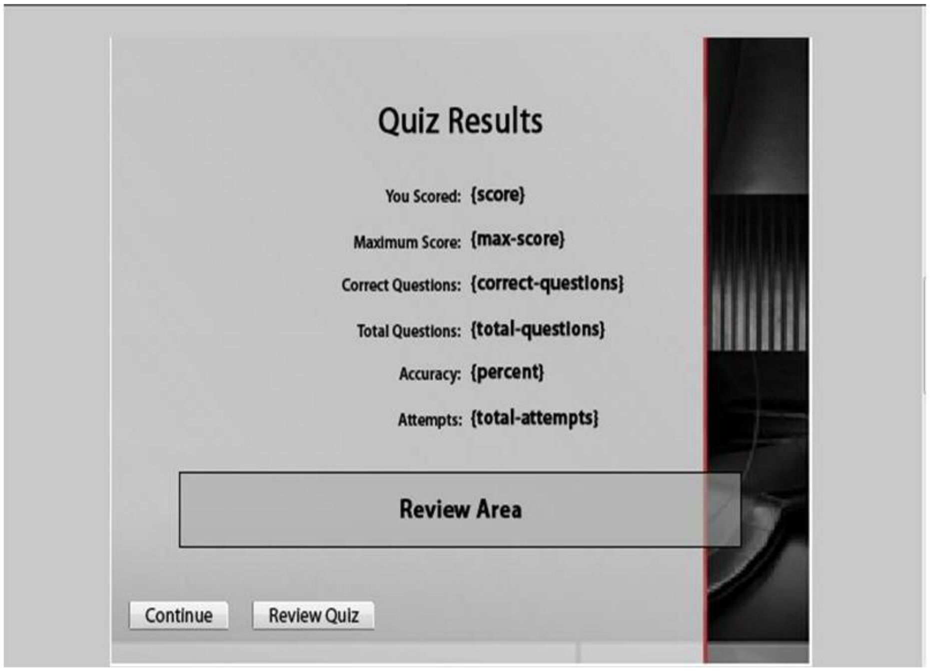

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