”Increasing students’ conceptual understanding of AC circuits: An application of Licht’s model”

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Increasing students' conceptual understanding of alternating current (AC) circuits: An application of Licht's model

Abstract

The complexity of AC circuit concepts warrants the application of an instructional method that presents the concept in an iterative manner. This is aimed at helping students appreciate the changing nature of alternating current while learning about the discrete function of electrical quantities and circuit components. The dynamic nature of alternating current and student's lack of pre-conceived notions about electricity makes this task of teaching and learning immensely difficult. This difficulty can be attributed to students' inability to link AC circuit phenomena to everyday practices or experiences. Students tend to think of the science and science learning in a concrete sequential manner. Consequently, students have a tendency to rely heavily on concrete concepts with which the abstract nature of AC circuits does not easily comply. As a result, improper instructional approaches to complex concepts such as AC circuits causes deeply rooted misconceptions when students attempt to assimilate the new knowledge of AC circuits with their previously taught direct current (DC) circuit framework. In order to increase students understanding of AC concepts, a new approach to instruction and course delivery is required in which AC circuits are taught as an entirely new concept while appealing to students' inductive and deductive reasoning ability. Using a five step model [1] which includes 1) using a phenomenological overview, 2) a macroscopic qualitative approach 3) a microscopic approach 4) a macroscopic quantitative approach and 5) a microscopic qualitative approach, this paper suggests the redesign of electrical courses aimed at increasing students' conceptual understanding about AC circuits. This work will not only provide information on a holistic approach to delivering and teaching AC circuit concepts but will also provide an alternative framework that can be applied to teaching other complex scientific concepts.

Background

In engineering learning environments, students are presented with the information throughout the lecture class which is followed by class activities relating to the presented information [2]. Introductory and advanced electrical circuit courses in engineering departments are usually taught using the traditional approach to teaching and learning. The information provided in course outlines suggests students are expected to understand that there is a certain measure of mathematics and science learning involved in these courses. This is sometimes reinforced by the grade students are required to have attained in pre-requisite courses before enrolling in the advanced courses. In most cases, engineering circuit course classes meet twice a week. The first class meet is usually a theory class with a lecture style approach where the instructor gives the students the lesson notes relating to that particular class and has discussions about the concept or concepts of the day. Typically, there might be some mathematical work involved but this is not always the case. At the second meeting of the class, students are given laboratory work, led by a teaching assistant, which most times include the creation of physical circuits or the simulation of the circuit in order to test for expected values. These measured values are then used to prove values that were previous calculated outside of the class. The basic requirement is that students complete all class activities in the time allotted as well the completion of all assigned laboratory work within the lab session. This situation leads to disconnect between the theory and laboratory exercise in some cases due to the fact that students are mostly given free range of their scheduled laboratory times as long as they produce the required documentation at the end of the session. This being the case, students are sometimes left not quite understanding the basic underlying principles of circuits which transcends throughout the entire duration of their course of study. When this happens, students may achieve good grades for the lab work and the overall course but they lack a complete understanding of the principles they were taught which tends to re-surface in their other classes [3].

In order to ensure students' understanding of circuit concepts, with specific focus on alternating current (AC) circuits, is increased there would have to be direct changes made to the current curriculum so as to modify the instructional process associated with teaching circuits. Researchers have recommended that in order for students to have a complete and lasting understanding of the concept of alternating current (AC) circuits, certain innovative instructional approaches have to be employed at the very introduction of the concept and followed throughout the delivery of information. Measures such as encouraging students in developing qualitative reasoning skills [4], the use of multiple representational models of the concept [5], employing special approaches to instruction that capitalizes on the intersection of macro, micro and symbolic levels of a concept [6][7] as well as infusing cyclically simultaneous causation thinking [8] have to be included in the selected approach and applied throughout the duration of the course.

Teaching and learning alternating current (AC) circuits

While electrical circuits are usually introduced in physics classes, as students become more advanced in electrical engineering courses, the level of complexity increases and therefore requires a more in-depth approach to instruction. When teaching AC concepts, measures should be taken to ensure that students understand the importance of all the intervening factors without being led to believe that any one aspect is more important than the other. Visual representations, equations and concept theories should be discussed as having equal roles as opposed to more focus being placed on manipulating formulas during problem solving rather than accounting for the underlying unchanging principles associated with the circuit. Students initial conceptual models for understanding new information causes them to think of a direct relation between the nature of knowledge and abstract concepts [9]. This therefore leads to misconceptions when formal instruction presents materials that conflict with their initial belief.

Due to their tendency to think that the current in a circuit is the effect of the function of a component at that particular point in time, students are unable to think of alternating current acting not as a straight line value but actually having cycles [10]. With this being the case, students should be instructed in such a manner that they are encouraged to think about current as not only the emergence of an action from the source of the circuit but as a cycle of electrons that are always present within the conductors used in a circuit. The use of iterative models of scientific concept teaching is an acceptable approach in developing in students the ability to consider cyclically simultaneous causation where a circuit is considered as a whole system instead of focusing on its parts [11]. In guaranteeing the teaching and learning of AC circuit concepts, suggestions have been made for the application of an instructional method that presents the concept in an iterative manner. Having students learn about these concepts in a repeated manner helps them to appreciate the time-varying nature of alternating current while learning about the electrical quantities and the function of various circuit components. It is the complex nature of alternating current and student's lack of pre-conceived notions about electricity that makes this task immensely difficult. This stems from students' inability to link AC circuit phenomena to everyday practices or experiences. Due to the nature of their learning compounded by how they view the learning of scientific concepts, students will have a tendency to rely heavily on concrete tasks and concepts which the abstract nature of AC circuits does not easily comply with. As a result, improper instructional approaches to complex concepts such as AC circuits causes deep rooted misconceptions when students attempt to assimilate the new knowledge of AC circuits with their current DC circuits framework. In order to increase students understanding of AC concepts, a new approach to instruction and course delivery is required in which AC circuits are taught as an entirely new concept while appealing to students' inductive and deductive reasoning ability.

Model for curriculum redesign

This five step model being suggested for the use of redesigning the curriculum to increase students' understanding and retention of AC circuit concepts has always been aimed at the teaching and learning of electrical concepts. Peter Licht [1] created this framework in order to overcome some of the common misconceptions students hold about electricity and electric circuits. Using a group of mixed ability students, aged 14 to 17, who had at least twenty (20) lessons on the topic of electricity, preliminary tests were done so as to ascertain students' understanding of basic electrical concepts. It was found that even after extensive teaching on the topic students still only had vague ideas about quantities such as current or voltage. Consequently, this framework was developed with the intention of creating innovative approach to the process of teaching and learning electricity. Licht [1] discusses a hierarchical approach to teaching the same concept would not only increase students' understanding but also reduce the development of misconceptions caused by conceptual difficulties in reasoning and understanding. This model would be applicable to the teaching of advanced concepts such as AC circuits since it has been theorized that students transfer the same misconceptions from simple electric circuits to more complex topics [14]. In addition, it has also been discussed students' inability to deal with the abstract nature of AC circuits renders them incapable of understanding the function of individual components within a circuit [8]. Applying this model will afford students the opportunity to learn about AC circuit concepts in a step-by-step manner with each level being a foundation for the other but each having separate goals in terms of what the student will learn. This model has five levels; each will be discussed in terms of what activities it stipulates and how the level would be beneficial in promoting students understanding of the concept being explored separately. These levels are:

1. A phenomenological orientation
2. A qualitative macroscopic approach
3. A qualitative microscopic approach
4. A quantitative macroscopic approach
5. A quantitative microscopic approach

Level 1 – Phenomenological orientation

The first step of this model is to provide students with a general overview about electric circuits with emphasis placed directly observable variables of circuits of a physical nature. Students are inclined to think about circuits in three aspects: sequential, local or superposition. Through their tendency to attribute the same properties of current to voltage and resistance interchangeably "they will tend to change their reasoning patters to suit the question at hand" (p. 98) [12]. At this level, this tendency would be addressed since the overview approach would cause students to realize that in a circuit there are numerous variables at play and that the operation of the circuit is dependent on the function each variable accounts for and as such they should be treated differently. According to Perkins [13], under his first principle of "Playing the whole game" students benefit more from the learning process when they are made to see the "big picture". This principle suggests that students should be made to see what the overarching concept is and how the smaller pieces fit.

Similarly, the learning of complex scientific concepts occurs when macro, micro and symbolic approaches intersect [7]. Students must be brought to appreciate each facet of a complex concept as an integral part of the concept before they are expected to make tenable conceptual links between them. At this level, the objective is to provide students with the opportunity to discuss their beliefs about what is happening in the circuit and why it happens as a means of becoming familiar with electric circuit phenomena. The use of language is very basic as technical jargons are avoided. While this introduction might be considered contextually bound and not easily transferred to other settings, it has been argued students must be first made to understand the concept of an electrical circuit before they are exposed to domain specific concepts, such as current, voltage and power, related to circuits [14][15]. In addition, providing students with circuit overview would not only prepare them for the more in-depth information that would follow but would provide the instructor with an assurance that students' understanding have been properly developed regarding the concept of circuits.

Level 2 – A qualitative macroscopic approach

At this level, students would be introduced to more specific information about circuit behaviour after having been exposed to electrical circuit phenomena. Terms such as voltage and current are discussed but without the use of micro-level concepts such as electrons or polarity charges. Students should be made to know the importance of understanding and using the correct terminology when discussing electric concepts as this can have significant impact on their conceptions about circuits which may become ingrained and ultimately conflict with scientific reasoning [3]. The lack of prior experience or conceptual understanding of electricity and concept notations are common areas of difficulty in learning about circuits. Consequently, any approach to instruction that does not allow for qualitative reasoning permits students from being able to develop deep conceptual understanding of circuits [16]. The macroscopic qualitative level then becomes important since current and voltage has been discussed as points of difficulty when learning about circuits. This slow transition into the use of these terms affords instructors and students the ability to completely learn about the concepts of current and voltage which are often times used interchangeably while still gaining further understanding of the AC circuit concept.

Level 3 – A qualitative microscopic approach

At the qualitative microscopic level, specific terms such as electrons and charged particles are introduced with the hope that students would develop the ability to switch between macroscopic and microscopic domains of reasoning. In addition to further cement qualitative microscopic concepts, the instructor would use visual representations such as circuit illustrations and simulation software in order to provide students some means of assimilating a vague concept such as voltage with something they can relate to. This aspect is very important because unlike science concepts, students hold no pre-conception of electricity. It has also been suggested that the misconceptions that students develop in relation to electricity comes from their interaction with formal instruction [17][18]. This therefore suggests students' lack of naïve physical intuition of circuit concepts such as voltage, current and resistance warrants the use of multiple representational models [19]. However, the use of visual representation is not very productive if students do not have a good understanding of why these representations are important to learn. Consequently, the relationship between macroscopic and microscopic qualitative instruction is precarious if not approached in a correct and concrete manner. With this limitation in mind, the instructor has to ensure that analogies and illustrations, if used, present students with applicable examples they can relate to.

Level 4 – A quantitative macroscopic approach

When students have been given in-depth exposure to the circuit concepts and assessed in order to determine their understanding of said concepts, the use of mathematical equations and formulas should be employed to make the abstract more explicit. When teaching complex scientific concepts that are heavily influenced by mathematical representation, the appropriate approach is to delay the introduction of mathematical models until after students have developed a grounded framework for the concept [18][20]. Mathematical or quantitative measures should not be used as the primary means of discussing or explaining circuit phenomena, instead it should be applied as a complementary approach to represent a concept that has already been established, discussed and understood. Licht's model [1] follows this orientation since concepts are taught first using a qualitative approach before the infusion of quantitative measures. An approach to teaching complex circuit concepts which stresses the use of formulas and equations at the very beginning of instruction, leads students to believe one factor or aspect is more important than the other. Like the qualitative approach, discussed earlier, students should be given the overall picture of the quantitative relationships between variables such as the use of ohm's law to express the relationship between current, voltage and resistance before the more integral aspects of the equation are introduced.

Level 5 – A quantitative microscopic approach

Students should be given the opportunity to explore and verify the relationship among variables through the use of equations and formulas. In order to ensure students completely understand the fundamental underlying relationship among variables within a working circuit, instruction should highlight the microscopic level of equations meaning students should be able to fully understand how variables are related as well develop the ability to derive equations from textual information. Instruction on the use of mathematical equations and quantitative approaches to learning AC circuits should go beyond the rote learning and application of formula. Students should be made to understand what makes one formula more appropriate for use over another, what relationship the formula represents and why it is the formula to be used for the solving of the given problem [6]. At the quantitative microscopic level, students have complete comprehension of how the circuit operates through the interacting of all the components functioning both in silo and collectively and possess the ability to use quantitative approaches to support their understanding.

Implementation of Licht's Model

As discussed previously in the five levels of Licht's model, any instructional approach to the teaching and learning of AC circuit concepts needs to inclusive of qualitative and quantitative reasoning skills while employing a multiple representational model. The curriculum that would employ all three facets would then be such that the circuit concepts to be taught are presented using all aspects. Since direct current (DC) circuits are physically more simplistic than AC, though not conceptual, it would be assumed that students have been exposed to the DC circuit concept before they attempt to learn about AC circuits. However, the drawback in this approach is that AC circuits are generally taught as an extension of DC circuits based on their fundamental similarities. This new curriculum design would treat AC circuits separate from DC in that while students are assumed to have the foundational knowledge about how a circuit operates the AC concept would be taught while making very little reference to DC circuits, if any at all. At any given time students would be engaging with the course material in a manner that causes them to be exposed to the qualitative and quantitative on the macro and micro level.

Findings from a previous study [10] suggests that when students are instructed using a unified model which includes intermediate instruction on current, voltage and resistance in a hierarchical manner where each concepts builds on the other, the overall understanding is improved. The delivery of the course material would be of such that:

1. At the beginning of the course students are given a general overview of AC circuits, all concepts to be taught will be treated in such a manner that students have a complete idea of what each entails before they are given an in-depth discussion about the respective concept.
2. Since the literature has indicated that the concept of voltage and current are common areas of misconceptions as students tend to think of them as the same concept, efforts would be made through the use of activities, graphs and simulations to present them at all times as two fundamentally different concepts.
3. A continuity of idea will be employed, meaning all activities, lab work, simulation, and in-class discussion will be to present different sides of the same concept. Using the recommendation of the model, students would go through each level for every concept to be taught. This would therefore mean that students would have to master each concept on all levels before the new concept is introduced. Assessment in this regard would of such that students are assessed formatively, from concept to concept and then the usual summative assessment at the end of the course. In order to assess students' qualitative reasoning skills, the assessment activities would consist of open-ended items that would require students to respond to questions in discussion form. Similarly, the quantitative aspect would be assessed based on students' ability to present their solution in a step-by-

step manner that is logical and demonstrates their complete understanding of the application they are using.

It is believed that the use of this model would increase students' understanding of AC circuit concepts while reducing the development of misconceptions. In addition, this model suggests a student-centred approach that makes the teaching/learning process the responsibility of both instructor and students. This partnership warrants the involvement of both parties in the change process if it is to be effective. This five step approach to teaching/learning can be implemented within a current curriculum without much change to the present system being required. Faculty members or instructors of AC circuit courses can simply modify their mode of lesson delivery to incorporate Licht's [1] five levels as was previously discussed. In addition, application of this model would reinforce the importance of both qualitative and quantitative knowledge about electric circuit concepts with both approaches being taught as having equal importance. Students' conceptual understanding would not only be dependent on their ability to solve problems but to be able to discuss and explain why these mathematical relationships exist and how it affects the overall operation of any circuit.

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