Technical-Vocational Education (TVE) High School Students' Conceptual Understanding and Mental Models about Electric Circuits

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Abstract

The study investigated the robust conceptions of Technical-Vocational Education (TVE) high school students about electric circuits to identify their mental models and to enumerate the teaching and learning implications of these conceptions and mental models. Using a descriptive design in snapshot approach, one hundred and ninety-five (195) students, specializing in Electrical Installation and Maintenance (EIM) from Grade 8 (n=88), Grade 9 (n=88), Grade 10 (n=4), and Grade 11 (n=15), took the diagnostic test Determining the Resistive Electric Circuits Concepts Test (DIRECT). Interview was used as follow-up tool to qualitatively assess the students' reasoning. The results were interpreted using both quantitative and qualitative analysis. The study showed that majority of the students have misconceptions and incomplete conceptions about electric circuits and the elements that make a circuit work. While they showed familiarity with actual circuit elements, they lacked familiarity with the symbols used in an electric circuit. The TVE students had varied understanding about how energy flows in an electric circuit. Some students subscribed to the Unipolar Model, the idea that electrical energy flows from the negative terminal only. The Bipolar Model was also present among the students, with the students describing the current from the positive terminal moving faster than the current that flows out of the negative terminal. The students' self-constructed idea about what happens when the energy reaches the load is analogous to a two-way traffic model. In teaching the TVE high school students, there is a need to reinforce their technical learning by acquiring conceptual understanding of electric circuits in their Physics classes.

Keywords: *Technical-Vocational Education, conceptual understanding, mental models, electricity, electric circuits, high school students*

1. Introduction

Science plays a prominent role in social and economic change [1] not only because it is responsible for describing how the natural world and the universe behaves, but also because it is responsible for determining the economic, cultural, technological, and social development of a nation, and of each generation. As such, academic institutions are crucially important for enhancing knowledge, particularly in the pursuit of truth and in providing and enhancing skills.

In the Philippines, the introduction of Senior High School in the educational system enacted through the Enhanced Basic Education Act of 2013 aims to achieve the goals of establishing and maintaining a new educational system relevant to the needs of the people, the country, and the society. This law mandates the educational institutions in the secondary level to enhance knowledge and skills, and prepare the learners, while continuing to inculcate fundamental concepts offered by core subjects, such as Science and Mathematics.

The United Nations Educational, Scientific, and Cultural Organization (UNESCO) emphasizes that Technical-Vocational Education (TVE) must be a preparation for occupation and employment. This is also interpreted as the development of ways of learning and the acquisition of skills and attitudes that result to success in the workplace. Its goal is tied to the idea of leading learners to acquire knowledge and develop practical skills necessary for employment in an occupation or trade. Despite the specific and descriptive UNESCO recommendations, the importance given to technical and vocational education varies very differently around the world. Guidelines for the implementation are redesigned according to the local demands and culture [2]. For example, eastern Asian countries such as South Korea and Japan invest highly in technical and vocational training to address the demand for skill-specific workers [3]. These countries have introduced strict qualifying procedures to categorize students who will qualify for University enrolment and those who are suited for technical training as well as to identify specializations suitable for the learners.

UNESCO recommends that the TVE specializations be promoted beginning the age of fifteen, the age when the learners are expected to have taken the general core academic subjects such as Mathematics and Physics [4]. However, the Malaysian Ministry of Education implements Technical and Vocational Education (TVE) as early as in primary school years, where grade school pupils are introduced to various strands of technical and vocational training [5].
The Philippines' Department of Education implements TVE as early as the age range of twelve to thirteen years old (grade seven) in technical-vocational schools. Selected secondary schools in the country implement the Strengthened Technical-Vocational Education Program (STVEP). The implementation of TVE across the secondary education is seen as a tool to achieving a satisfactory population that has acquired the required skills for actual employment.
Technical-vocational institutions encourage critical and creative thinking skills by disseminating scientific and technological knowledge. It is in this principle that teachers of Physics in technical and vocational education institutions must understand the nature of the specialized needs of students in this program [4]. A curriculum, teaching strategy, or material should therefore be modelled to address the demands of effective technical and vocational education. The curriculum design must be that type which provides the learners with the basic scientific knowledge and attitude alongside with the skills they are expected to acquire from technical education in the local and global context.
Technical Vocational Education (TVE) is an educational design intended to prepare members of work-ready population. In the Philippine setting, there are select schools implementing STVEP alongside the K-12 curriculum. These curricula are designed to be consistent with the recommendations of UNESCO where the teaching and learning processes are expected to provide learners with technical and vocational skills along with the basic knowledge in the sciences. Among the basic knowledge are the core competencies that would be provided by Physics education. This would train the students into a scientific way of thinking [6] and would help in understanding how things work and how the environment behaves. However, despite the structured curricula and specialized teaching strategies, there are still misconceptions that prevail among the students. Among the topics with several misconceptions in Physics is electrical circuits which had been a focus of several studies [7-10].
The related studies and literature about physics and technical vocational education provided the framework that the researchers used as the basis for this study.

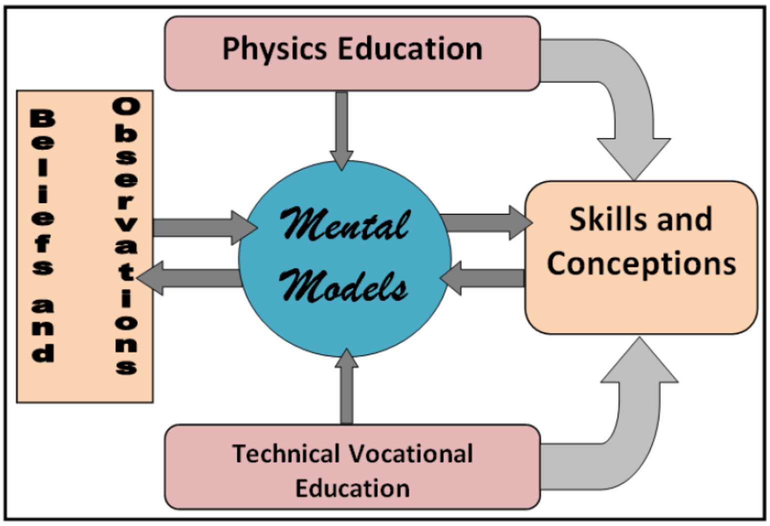

Figure 1. Framework for the Study

The learners' mental models were pre-developed by their personal observations and beliefs of things and events. Their skills and conceptions were expected to reshape their mental models through Physics education as well as Technical Vocational education in formal schooling. In turn, their mental models further affected their beliefs and the way they observed things and events.

2. Methodology

The setting of the study is a secondary school in Makati City, Philippines that implements the Strengthened Technical-Vocational Education Program (STVEP). Using a descriptive design in snapshot approach, one hundred and ninety-five (195) students, specializing in Electrical Installation and Maintenance (EIM) from Grade 8 (n=88), Grade 9 (n=88), Grade 10 (n=4), and Grade 11 (n=15),

took the diagnostic test, Determining the Resistive Electric Circuits Concepts Test (DIRECT) [11]. DIRECT is a 29-item multiple-choice diagnostic test designed for high school and college students that aims to determine the misconceptions of students about electric circuits. The test has a discrimination index of 0.23, difficulty index of 0.41, and Kuder-Richardson formula (KR-20) value of 0.70.
An interview was used as a follow-up tool to qualitatively assess the students' reasoning. Eleven out of the 195 students were interviewed. During the interview, they were asked to explain why they chose the answer for each item in the DIRECT questionnaire. The researcher asked probing questions to draw students' reasoning. They were allowed to speak in either Filipino or English, depending on their preference. They were reminded of their answers before the interview, but they were not aware whether their answer was correct or incorrect. At the end of the interview, a concept map summary was made from the students' description of how electrical circuits behave.
The results were interpreted using both quantitative and qualitative analysis.

3. Results and Discussion

Figure 2 presents the frequency count of students who obtained a particular score in the DIRECT. The graph is skewed to the left, which means that the students' understanding of the concepts in the topic of electricity is low. These results, however, are comparable to the results obtained in a study [12] conducted on Grade 10 students, where the researchers obtained a mean score of around nine out of a total perfect score of twenty-nine. The relatively low scores obtained for the DIRECT test may be attributed to students' difficulty in visualizing the concepts of voltage, current, and resistance, particularly because they cannot be directly observed, unlike other Physics concepts of force, velocity, and acceleration.

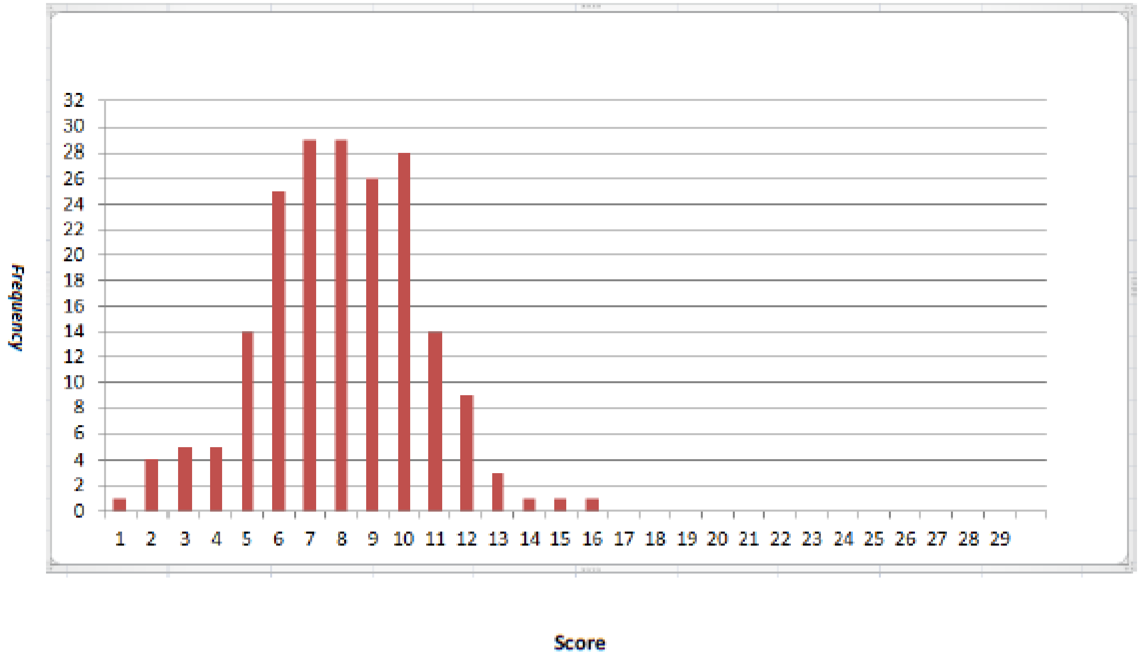

Figure 2. Frequency vs. Score Graph of the TVE Students in the DIRECT test

The data in the current study showed that majority of the students have misconceptions and incomplete conceptions about electric circuits and the elements that make a circuit work. While they showed familiarity with actual circuit elements, they lacked familiarity with the symbols used in an electric circuit. One example is the evident confusion about the differences of terms like current, voltage, resistance, and power. Almost all the interviewed students used resistance, energy, and current interchangeably, as if these quantities have the same meaning.

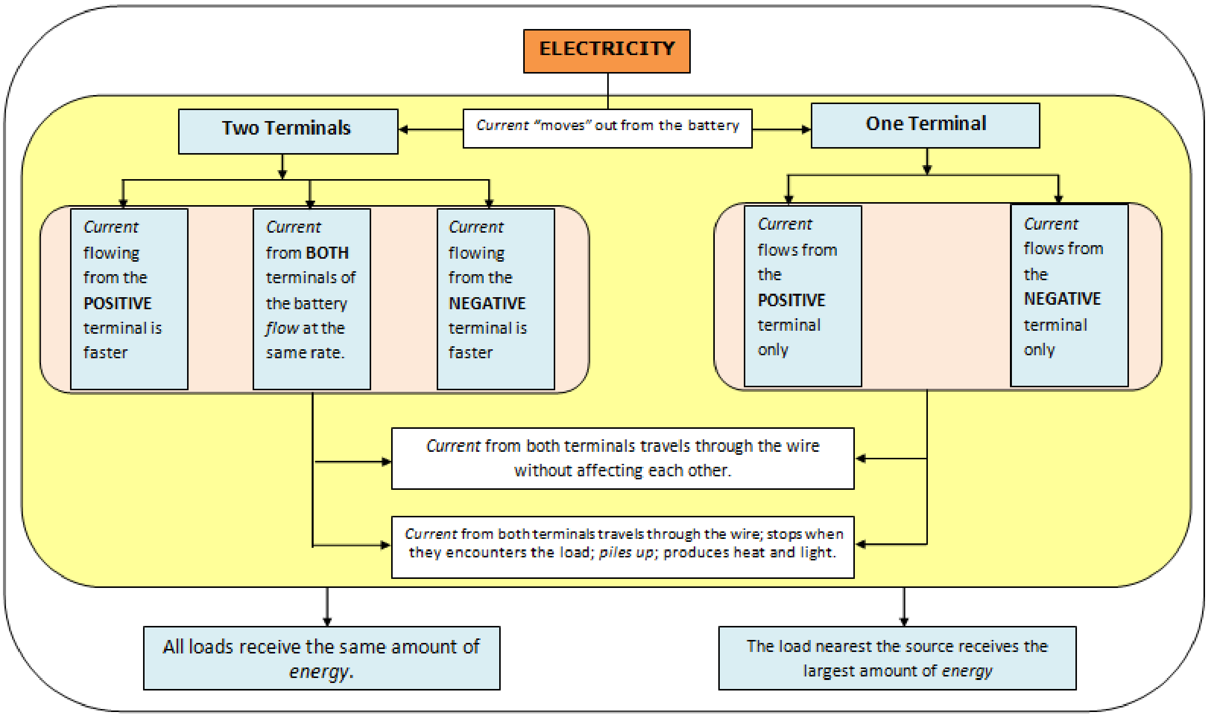

Figure 3. Concept Map of the Students' Mental Models

There were varied understanding about how energy flows in a circuit. Figure 3 presents the TVE students' concept map. One idea that emerged is that electrical energy flows from the negative terminal only, while there was another idea that energy flows from positive terminal only. This is similar to the Unipolar Model proposed by Isola [7] in his study, but with a specific terminal source. The Bipolar Model is also present among the students. In the case of the TVE students, the Bipolar Model contains a more specific description as to how fast or what direction the energy flows from both directions. One description was that energy flows from both terminals of the battery, but the current from the positive terminal moves faster than the one that flows out of the negative terminal. Another description states that energy flows from both terminals of the battery at the same speed.

The students also have their self-constructed idea about what happens when the energy finally reaches the load. Some of these descriptions used the road traffic flow as an analogy and explains what happens when the flow from the opposite directions meets. One model suggests that the two opposite energies pass by the load without affecting each other. This can be compared to a two-way traffic that flows smoothly and uninterruptedly.

Another model found among the students is similar to the two-way traffic analogy, the only difference was that the load was described as something that would interrupt the flow. This could be compared to the two-way traffic analogy, but with red traffic lights on, or any interruption on the road. In this model, current initially flows smoothly from both terminals of the battery. They then both stop when they reach the load. As more current flows from the battery, they "pile up" at the area where the load is located. This eventually causes heating up of the load, such as bulb, and results to the production of light.

The students also explained how energy is consumed by each load in a circuit. One idea explains that the load nearest the battery gets the highest amount of energy. This results to the succeeding loads getting lesser and lesser amount of energy. This is very different from a student concept which says that the amount of energy received by each load is equal to the amount of energy supplied by the battery regardless of how many loads are present in the circuit, or what type of connection the circuit has.

Another common idea was that energy is equally divided among all the loads. The greater number of loads present in the circuit means that the number of loads that will share the total amount of energy will be bigger, thus resulting to lower energy for each load.

4. Conclusion

Based on the Strengthened Technical-Vocational Education Program (STVEP) curriculum, the TVE students are expected to acquire the scientific foundation of electric circuits and as well as hands-on experience in electric circuits. Students create their own mental models to explain their experience or observation. These mental models may be scientifically accepted, naïve, incomplete, or totally wrong. It is important that students reinforce their technical learning by acquiring conceptual understanding of electric circuits through Physics education.

The results of the study showed that the TVE students were not able to acquire mastery of the lessons as shown in their low scores in the DIRECT test. The students hold several misconceptions about the different quantities involved in electric circuits.

Physics teachers in TVE institutions should give emphasis on foundational knowledge for the learning of electric circuits, including the nature of the important terms such as current, resistance, power, potential difference, and voltage.

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