

Apostolos Kaltsas, 2020

Volume 4 Issue 3, pp. 01-13

Date of Publication: 12th November 2020

DOI- <https://doi.org/10.20319/pijtel.2020.43.0113>

This paper can be cited as: Kaltsas, A. (2020). Vocational High Schools Students' Views on the Circulation of the Electric Current in the Electronic Control Unit (ECU) of the Modern Cars. PUPIL: International Journal of Teaching, Education and Learning, 4(3), 01-13.

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VOCATIONAL HIGH SCHOOLS STUDENTS' VIEWS ON THE CIRCULATION OF THE ELECTRIC CURRENT IN THE ELECTRONIC CONTROL UNIT (ECU) OF THE MODERN CARS

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Abstract

An electronic control unit (ECU) is any embedded system in automotive electronics that controls one or more of the electrical systems or subsystems in a vehicle. Its purpose is to control and process information by converting it into electrical signals to be recognized. This paper presents the results of research on students' views on how the ECU electrical signals of modern cars are represented in their minds and what mental current model they adopt. The literature on students' views about electric current states that they adopt 4 models: The monopolar model, the conflicting currents model, the consumer model, and the scientific model, which is the scientifically accepted. The survey was conducted through a semi-structured interview where respondents were free to talk about the issue and give their views. 26 students (21 boys and 5 girls) of Vocational High Schools (specialty "Vehicle Technician") from the prefecture of Attica participated. The analysis of the results showed that 15.4% of the students adopted the monopolar model, 30.8% the conflicting currents model, 26.9% the consumer model while the same percentage (26.9%) adopted the scientific model where it turns out that the scientific model approach does not seem to be achieved

satisfactorily. It was also found that students' views were influenced by their previous knowledge and experiences with other modern devices such as mobile phones. In conclusion, it is imperative that teachers, by designing appropriate teaching interventions, inspire and guide students in intensifying their study of the characteristics of CPU electrical signals in order to increase their interest and approach to the scientific model.

Keywords

Electronic Control Unit, Vocational High Schools, Electrical Signals, Phenomena, Students' Views, Electric Current, Mental Models

1. Introduction

Due to ever-increasing demand, the electronics industry has been growing at a rapid pace, and the Electronic Equipment has become one of the key problems in the modern world (Meninkpura et al., 2016). We find an important application of electronic circuits in cars and specifically in the car electronic control unit (ECU). The ECU is made up of a set of integrated circuits and is designed to control every system in the car. Its purpose is to control and process information by converting it into electrical signals. Students' understanding of CPU power flow is an important factor in being able to fully learn how it works. ECU's have become a standard device on most cars since the late 1970s when they became necessary due to increasingly stringent government emission standards. The ECU uses closed-loop control, a control scheme that monitors outputs of a system to control the inputs to a system, managing the emissions and fuel economy of the engine (as well as a host of other parameters). Gathering data from dozens of different sensors, the ECU knows everything from the coolant temperature, to the amount of oxygen in the exhaust. With this data, the ECU performs millions of calculations each second, including looking up values in tables, calculating the results of long equations to decide on the best spark timing, and determining how long the fuel injector is open. The ECU does all of this to ensure the lowest emissions and best mileage. The research topic of this work is the recording of ideas and models related to electricity in the students of the specialty "Vehicle Technician". Many researchers argue that children's alternative ideas, which they also call students' science, are not ordinary, trivial errors, but mental constructs that children use to interpret phenomena. In this sense, children's ideas are autonomous forms, but they differ from the scientific standard in that they interpret phenomena differently (Gilbert et al., 1982). Children's perceptions are often different from the scientific

standard as presented in school books. However, these perceptions are useful and logical because they are the skeleton of the interpretation of the relevant phenomena. The comparison of the models mentioned by the students could lead to the creation of better educational material with the ultimate goal of designing appropriate didactic interventions. Through the interview process, students can report their views on electricity inside the car's electronic control unit (ECU). The need for the research arises from the fact that although there are several studies on electricity, there are no relevant studies that refer to the car CPU (Engelhardt & Beichner, 2004).

2. Conceptual Framework

With this analytical tool we can get a comprehensive understanding and explain the following key concepts:

2.1 Electric Current

Electric current is the directed movement of electric charges or electric charge carriers along a power line. Electric charge is carried by charged particles, so an electric current is a flow of charged particles. The moving particles are called charge carriers, and indifferent conductors may be different types of particles. In electric circuits, the charge carriers are often electrons moving through a wire. It is measured in units of current intensity and corresponds to a changing magnetic field. The International System of Units (SI) unit of electric current is the ampere or amp (symbol: A), which is the flow of electric charge across a surface at the rate of one coulomb per second. Electric current is measured using a device called « ammeter» (En.Wikipedia.Org/Wiki).

2.2 Electronic Control Unit (ECU)

An electronic control unit (ECU) controls one or more of the electrical systems or subsystems in a vehicle by converting information into electrical signals. Types of ECU include engine control module (ECM), powertrain control module (PCM), Transmission Control Module (TCM), Brake Control Module (BCM or EBCM), Central Control Module (CCM), Central Timing Module (CTM), General Electronic Module (GEM), Body Control Module (BCM), Suspension Control Module (SCM), control unit, or control module. Taken together, these systems are sometimes referred to as the car's computer (technically there is no single computer but multiple ones). Sometimes one assembly incorporates several of the individual control modules (en.wikipedia.org/wiki).



Figure 1: *Car Electronic Control Unit (ECU)*

2.3 Students' Views on Phenomena

Students may have formed an opinion about some of the natural phenomena before they are taught in school. Their views are the result of their efforts to give meaning to the world in which they live by referring to their experiences, their current knowledge, and the language they use. An important role in their views is played by the influence of adults' perceptions, the teaching, the interaction with other children, the language used by adults, the media, etc. (Kokkotas, 2004). Students' views on phenomena are grouped and set up interpretive patterns that are usually recorded as alternative ideas or misconceptions, pre-existing ideas, representations, mental models. As far as electricity is concerned, the students' perceptions have been explored where with the appropriate didactic interventions they gradually develop a more complete and "scientific" view of electrical phenomena (Koumaras et al., 1990). However, there are surveys where they showed that even after extensive teaching; students remained in their previous perceptions of electricity (Christidou, 2001). In a study conducted in Turkey (Cepni & Keles, 2006) the aim was to investigate the conceptual

models used by 250 students of Primary and Secondary Education and students (aged 11-22, for circuits with two lamps and a battery (serial connection). In Turkey, students are taught electricity in school from the sixth grade of compulsory education onwards (from the age of 12). Data were collected from students' answers to open-ended questions, from the schemes they also made from the explanations they gave for these shapes. Data analysis was performed using both qualitative and quantitative methods. Specifically, most 11-year-olds (58%) who had not been taught any electricity at school used the monopolar model, 13-year-olds used the conflicting currents model in 22% and the current attenuation model or the 24% dividend model. The current attenuation model or the divisive model was used by half of the 16-year-old students, the 19-year-old students by 36%, and the 22-year-old students by 20%. The scientifically accepted model was used by 16-year-old students at a rate of 58%, 19-year-old students at a rate of 58%, and 22-year-old students at a rate of 72%.

2.4 Mental Models

A mental model is an internal analogical representation of certain situations or processes that has the role of helping the individual when trying to understand the cause or when trying to explain and predict the physical world. People do not perceive the world directly but through a mental representation of it, therefore the perception of any state is determined by the mental models we can construct (Johnson-Laird, 1983). Mental models help the function of memory and in predicting the behavior of physical systems. Mental models are classified into physical which represent the physical world (whether real or imaginary) and conceptually which are mental constructions of concepts, models, and abstract processes (Johnson-Laird, 1983).

An individual's ability to influence, control, or predict a physical phenomenon, which is the basis of his/her understanding, arises from the construction of functional mental models. When a person faces a situation, all the building blocks he/she uses to interpret it and the relationships between them constitute the internal representation that is a structural analogue of reality as perceived, so that it functions as a substitute for that reality. The manipulation of this substituent results in facilitating predictions of properties and relationships that are not obvious, (Greca & Moreira, 2001).

2.4.1 Mental Models of Electricity

- The monopolar model.

According to this, the current from one pole of the battery goes to the current consumer where everything is used.

- The model of conflicting currents.

Students believe that current - or both types of current, positive, and negative - flow from both poles of the battery to the consumer. In fact, they sometimes explain the existence of light in the context of the "collision" of two currents (Driver et al, 2000).

- The consumer model.

The model of conflicting currents is usually replaced in the sense that the current leaves one pole of the battery (usually the positive one), reaches the consumer, part of it is consumed there and the rest turns to the other pole (Shipstone, 1984).

- The scientific model.

This model is scientifically correct where the electric current flows in the circuit in a constant direction and is maintained.

3. Methodology

The specific procedures and techniques used to identify and analyze the research topic were as follows:

3.1 Aim of the Research

This paper aims to highlight the importance of considering students' perceptions and approaches to vocational high school mechanical engineering education in Greece. Whilst considering course delivery techniques for engineering students, it is also posited that understanding how students perceive their learning contexts is vital. Some of the ideas that children use about the natural world are so entrenched that they do not change with teaching. Moreover, although some children may apply scientific ideas to exam problems, they fail to apply them outside of school to interpret some phenomena so it is essential that we understand how these perceptions influence students' approaches to their studies (Tudor et al., 2010). The aim of the research was to detect and explore students' perceptions and alternative ideas about their views on the circulation of electricity in the ECU of modern cars so that we can design appropriate teaching interventions and students fully understand the function of ECU and the circulation of current in it.

3.2 Research Sample

The research was conducted in Vocational High Schools of the Prefecture of Attica in Greece. 26 students (21 boys and 5 girls) of the specialty "Vehicle Technician" participated. The specific students are in the 3rd grade of the Vocational High School, at the end of their twelve years of compulsory education. Their specialty is "Vehicle Technician" which belongs to the "Mechanical Sector". In Greece, in the Vocational High Schools, the students, when enrolling in the 2nd grade, select with their application the Sector they wish to attend. Students when enrolling in the 3rd class can join with their application in any specialty of the Sector that they attended in the 2nd grade. The sample of students was selected by the method of «simple random sampling». Simple random sampling is based on a random sampling process, such that each member of the population has the same chance of being included in the sample (Cohen & Manion, 2000). It is usually achieved by using a lottery or tables of random numbers. This procedure, in addition to eliminating any bias, allows the application of probability theory to calculate the sampling error. It requires a complete list of members of the population or at least the sampling frame.

3.3 Research Tool

In the present research, the qualitative approach was chosen and its main purpose was to understand, determine the breadth and depth of students' views. As a means of data collection, the interview methodology was used, which is a form of direct verbal communication between individuals. The interview is part of the qualitative research and is a basic method of collecting data and information. In research education, the interview is considered to be a more reliable research tool and to provide more data than written questionnaires (Cohen & Manion, 2000). A semi-structured interview was used, where the respondent can express his/her experiences and thoughts, giving the opportunity to the researcher to collect information that is objective and can be repeated. In addition, with the semi-structured interview, we can adapt to the results of the interview, gaining easily valuable information about the research (Paraskevas, 2003). Researchers with semi-structured interviews guide the participants to a certain extent, thus facilitating them significantly, as they focus on the research question and have the possibility to expand, but not to completely escape, making the interview unsuitable for drawing conclusions (Cohen & Manion, 1992). The participants supported their views freely and willingly to contribute to the research.

4. Results

Most reports (8 students, percentage 30.8%) are related to the category of the conflicting currents model. A female student states: "The car computer after processing the input signals sends current to the actuators which flow from both poles of the battery" (S12). Another male student states: "There are two (2) currents positive and negative which circulate from both poles of the battery to the control unit which meet each other" (S19).

The next reports (7 students, percentage 26.9%) are related to the category of the consumer model.

A male student states: "The control unit controls the various components that affect the operation of the engine and the current leaves the positive pole of the battery is consumed in the path it makes and the rest turns to the negative pole" (S22).

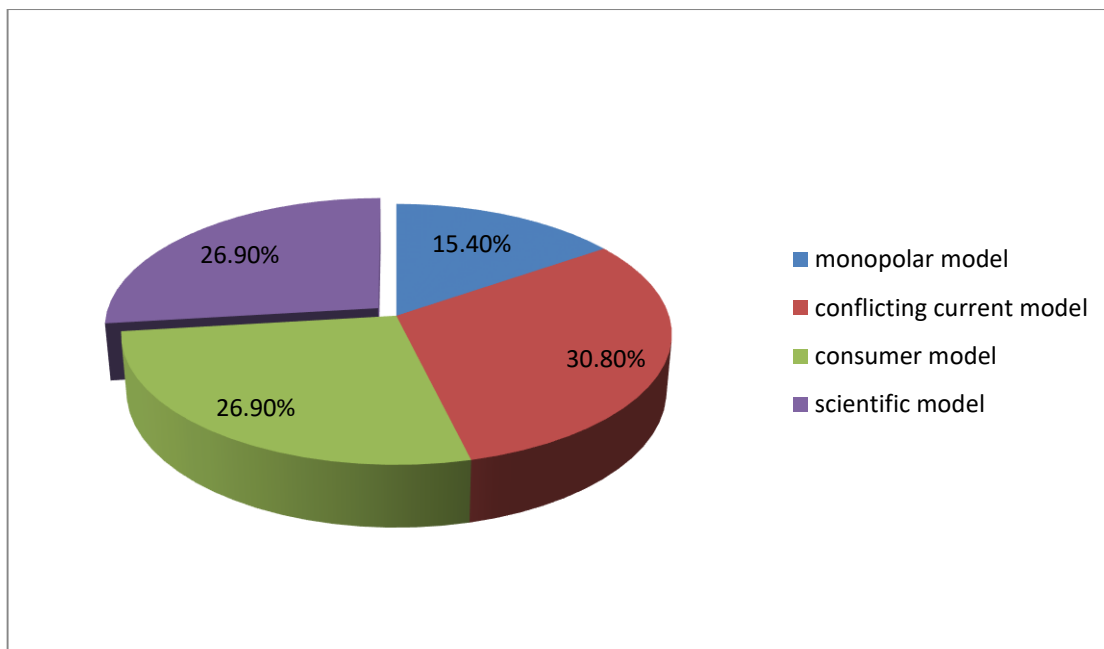


Figure 2: *Students' Preferred Mental Models of Electricity*

The same number of students (7, percentage 26.9%) state that they adopt the scientific model which is scientifically acceptable. A male student states: "The current flowing to the actuators is the same on both wires" (S17) while another female student states: "The current in all the circuits of the control unit always circulates at a constant time and is maintained" (S06).

The fewest reports (4 students, percentage 15.4%) are related to the category of the monopoly model. A male student states: "Sensors send electrical signals to the control unit which use only one cable to connect to the positive pole of the car battery" (S16). A female student states:

"I do not know if what I am saying is correct but simulation software would help me to understand it better" (S01).

Students' views are also often influenced by the devices they use in their daily lives such as mobile phones, computers. A male student states: "The CPU has smart circuits that cut off the power to the battery and reset it when it gives output signals as it does on cell phones when the battery is fully charged"(S04) while another male student states: "Since the car ECU is essentially a computer the power circulates in the same way as on the laptop I have at home"(S11).

5. Discussion

Students' pre-existing ideas about electricity can be approached using the appropriate educational software to approach the "scientific model". In contrast to the traditional approach to teaching, in the constructive approach, through a process of reflection, the students realize the limited and inapplicable of these ideas resulting in their reconstruction. By applying appropriate teaching strategies, students reflect on their ideas to assess whether they are functional and applicable. If these ideas are found to be inadequate, students are led into a "cognitive conflict", which will lead to the process of "conceptual change" (Koltsakis & Pierratos, 2006). "Cognitive conflict" is one of the processes aimed at achieving the reorganization of mental patterns into other broader, more complete, and closer to the scientific model. Achieving this conflict can be achieved either by refuting the results of an experiment or by realizing the existence of different views within the classroom (Osborne & Freyberg, 1985). Thus, it can be easier to try for a conceptual change, in such a way that they are more compatible with the scientific model.

6. Conclusion

Students' views on phenomena are grouped and interpreted as patterns that are usually recorded as children's alternative ideas or misunderstandings, pre-existing ideas, spontaneous perceptions, intuitive ideas, children's science, representations, or as mental models. Students' alternative ideas have generality and timelessness, although some of them differ from student development or with the impact of teaching. These ideas are sufficient for students to interpret phenomena and constitute a cognitive structure with limited power. Many times they are little influenced by traditional or experimental teaching (Psillos et al., 1988). Each student has a level of knowledge and therefore the teacher should identify the content of these perceptions and then, with

the help of the textbook and new technologies, reconstruct the points of these perceptions that do not agree with reality (Alexandropoulos, 2020). The circulation of electricity in the car ECU is associated with many misconceptions about how electricity is presented in a conduit (where it is "created", how it is "created") is a "mysterious" reality for students because effects of the current are obvious, but the same is not immediately visible, so it is necessary to know the perceptions of students so that with the right teaching to avoid creating misunderstandings or incomplete perceptions (Osborne, 1981). It is also argued that high school leavers with a better background in sciences, mathematics, and language are expected to have higher education efficiency in the study process at university (Sek et al, 2018).

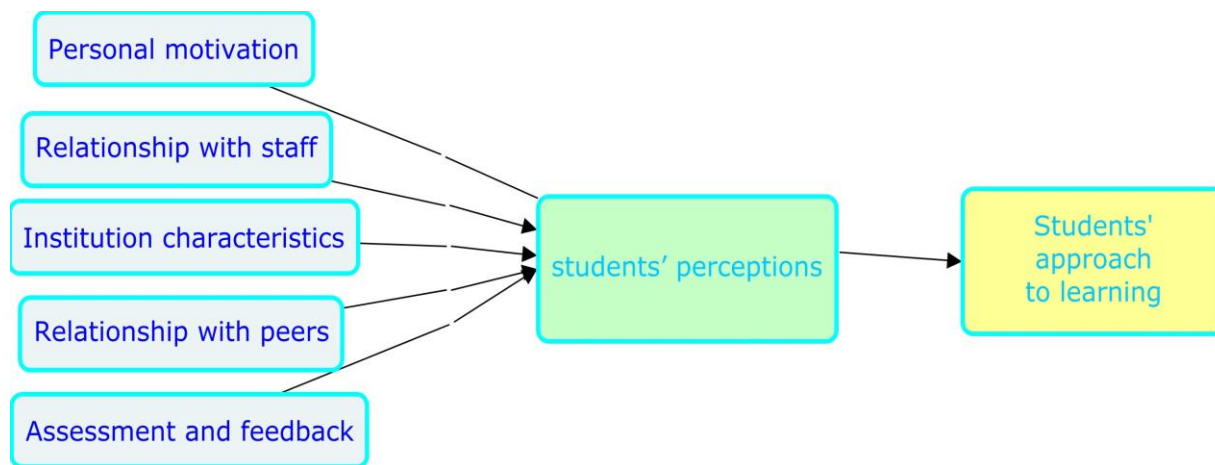


Figure 3: *A Theoretical Framework for Considering Students' Perceptions and Approaches to Learning*

The research showed that the scientific model approach does not seem to be achieved to a satisfactory degree even though the students are in the last grade (C) of their compulsory education. From the students' side, it seemed that there was a concern about the way the electricity is conducted from the battery cables of the modern car to the electronic control unit. The need to strengthen students' interest in the role of electricity in the operation of the car control unit (ECU) with relevant questions and inquiries was also confirmed.

It is important for the effective teaching of the teacher of the specialty "Vehicle Technician" to know the conceptual models included in the curricula, as well as the mental models of the students for the courses that he is going to teach. In this way, he/she will be able to design didactic interventions where students will approach scientific models more effectively. Teaching interventions using ICT and educational software could greatly facilitate students in approaching the

scientific model given that a restructuring of the Secondary Education curriculum is necessary for this purpose.

Moreover, the experimental teaching by the method of simulation could bring positive results and help in students' approach to the scientific model while promoting the active participation of students. Still, it could eliminate pre-existing misconceptions of students.

7. Research Limitations

It should be noted that the sample size of students is small and not strictly randomly selected, so it cannot be considered as representative of the population it represents. For more reliable conclusions the research could be repeated in the future with a larger number of the sample as well as to investigate whether the students' views approached the scientific model after the end of the teaching interventions.

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