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Effect of Q-Net demonstration-based educational approach on improving students problem-solving skills in the electrical machines course

Julius Fusic S., Ramesh H., and Sharanya G
Department of Mechatronics, Thiagarajar College of Engineering, Tamil Nadu, India

***Abstract*— In order to balance the time and course load, the author aims to introduce a demonstration-based teaching approach that will assist students, master the necessary course content and improve their independent problem-solving ability in a very short period of time. This study recommends using demonstration sets of problem-based learning exercises to measure the level of knowledge (apply and analyze). Statistical tools were used to describe the impact of the electrical machine demonstration kit course in the Mechatronics Engineering curriculum and to analyze the internal results. Using these techniques, teachers expect students to have a better understanding of the basics of the machine after learning and experimenting. The questions are answered and the conclusions are verified by the students using simulators based on laboratory experiments. In addition, three different types of electric motors—servo motors, stepper motors, and brushless DC motors are used for the study to demonstrate the proposed learning technique. Three different types of motors are compared via theoretical analysis, modelling, and experimental verification. The majority of students are able to supplement themselves and reach the right conclusions based on an examination of their problem-solving techniques. The suggested strategy can aid students in developing their problem-solving skills.**

***Keywords*— Demonstration Kit, Problem solving skills, Creative question-based assessment, Q-NET, Electrical machines**

I. INTRODUCTION

The Problem-based teaching methods are popular. To develop students independent thinking and problem-solving skills, several institutions provide problem-based courses. The teacher and students education policy the proposed author cases detailed the pedagogical understanding of the program for individual student development, V.L. Akerson et.al (2014) and May M.H et.al (2013). Puzzle teaching strategies Merrick, K.E (2010), the problem-based teaching strategy

For example, researchers used an end session puzzle learning method and it took many weeks to complete the training process. The approaches like project and problem solving may take more time by students to understand the concepts. Unlike the three teaching techniques mentioned above, the author recommends using a small-problem-oriented teaching approach during the electric machine experiment to increase the teaching effect and strengthen students independent analysis and

Revelle, K.Z (2019) S. Beneke (2009), and the project-based teaching strategy are commonly used in all the three different ways for students to understand the lecture materials, Falkner,N et.al (2010) and Costa et.al (2007). In order to engage the students by introducing the puzzle or riddle based lecturing approach at the end of every session, Fusic et.al (2020). The thought-based approach to solving problems in a specific domain has no limitations and focuses on a few common mathematical principles of problem solving. In Woods et.al (1997), Fusic et.al (2021), Williams et.al (1994) the problems are addressed using a problem-based teaching strategy that broadly focuses on students knowledge rather than their skills. Students can use data analysis, theoretical analysis and teamwork to overcome obstacles and complete tasks. A Learning technique through problem-based approach requires a significant amount of professional skills to improve students problem-solving abilities. Project requirements are determined by the project-based learning technique in Richardson et.al (2011) and Tan et.al (2018) before they are addressed in the theoretical study, program design, and program implementation phases. When a specific function or purpose is required, challenging situations are addressed through the introduction of teaching learning approach using projects. The puzzle-based learning technique is a self-contained theory that does not require any specialized electrical engineering knowledge to solve macro-scale problems Fitriani et.al (2018). The problem-based learning method, which is based on concrete engineering experiences, offers precise tactics and techniques to achieve the goal. In addition to emphasizing problem solving and real-world technical applications adapted to different contexts, the project-based learning method relies on expertise in electrical engineering. When comparing the time and workload of the three teaching approaches, the puzzle-based approach takes a lot of time. For example, Falkner et.al (2010) used a puzzle-based teaching strategy and took many weeks to complete the training procedure. The puzzle-based learning approach requires the most time and workload compared to the other two. problem-solving skills. The focused course for Mechatronics engineering students is called "The Experiment of Electrical Machines." It focuses on energy conversion technology Acikgoz et.al (2019), Buccella et.al (2014), especially between mechanical and electrical forms. Electric machines are widely used in various fields, including power systems, industries, energy sectors, telecommunication department, personal computer sectors and other useful conventional methods Tamás et.al (2020) and You guang et.al (2006). The following four goals and requirements should be addressed by small-problem-based learning approaches:

(1) In the proposed work the demonstration-based approach reduces much time between students and teaching members for understanding the concept while compare with traditional approaches like project, puzzle or problem-based methods.
(2) Small demanding situations in the route can assist students enhance their assignment and hassle-solving skills.
(3) The given problem statement or issues must not be particularly difficult and their answer must not take a good deal more time.
(4) There should not be too many questions throughout the course and no more than two are appropriate.

Teachers can use the technique to select one-minute questions that will not be too difficult for most students to answer or that most students cannot answer without much thought and research. The following criteria are used to select small problems: (1) Students are not sure of the correct answer to the question that must be answered; (2) Students are not sure of the knowledge they should master in the subject Electrical Machines; and (3) Students may be capable of achieving a solution to this query by the usage of alternative techniques such as pure theoretical evaluation. However, the solution found through theoretical research, modeling and experimentation is more convincing. The proposed pedagogical approach is suitable for courses that follow theoretical lectures with experiments. Also, a 3rd or 4th year college student with some basic analytical skills is suitable. It can also be used in graduate courses. Graduate students are accustomed to the process of theoretical analysis, simulation, and experimentation in their research experience, so the educational effect differs from that of undergraduate courses.
The author demonstrates the impact of a learning approach based on small problems with a case study comparing the motor current and speed of three different types of motors. The innovative approach from the study only made the students to focus on the courses than the conventional approach. In this contribution, Chapter I presents the introductory part and related work. Chapter II demonstrates the contribution work approach used to analyze the demonstration approach among engineering students. Chapter III describes in detail an experimental case study to segregate and analyze individual students using Q-net hardware tools. Chapter IV provides the results and analysis of two groups of students with electrical machine experience. Chapter V presents the conclusion and future work on student engagement in various case studies.

II. PROPOSED WORK OVERVIEW AND CONTRIBUTION

The second-year students in the School of Mechatronics Engineering at Thiagarajar College of Engineering take a one-semester course called Electrical Machines. Electrical machine fundamentals like Servo motor, Stepper motor, and Brushless DC motor are covered in the course material. The primary goal of this path is to extend students expertise of the basics of electrical machines as a way to realize the topological shape, working principle, and control scheme of an ordinary system. For two years, 2021 and 2022, the conventional approach depended on lectures and laboratory experiments. The results of the traditional teaching strategy were unsatisfactory. Most students were unable to complete the experiment and were unable to find any answers to any questions without the instruction booklet. The correct percentage of curves and the percentage of correct answers were lower because the student was not capable of predicting the results of the experiment in advance. The ability to analyze and solve problems using basic knowledge discovered during the electric machine experiment was not referred to. A few of the students who attended the previous academic year (2018) and were taught using the small problem method. Students can learn techniques for analysis and problem solving by completing a series of small tasks or challenges. The author of this case study talks about a class called Experiment of Electrical Machines that had 60 Mechatronics engineering majors as participants. 2 groups of students each were formed from the student body. Due to the workload associated with the proposed small-problem teaching approach, four or five students had to work together to complete the task. It was cautioned that students with distinct degrees of success inside the direction exam form one group to support each other. Two lessons were scheduled in one week, each with two short questions. Three different types of electric motors are explored through theoretical study, computer modeling and student experiments. Engine simulation models can be distributed by professors to students to save time. In order to get the correct answer to the questions, students can also thoroughly analyze and learn the principles of how engines work. They then use simulation in the laboratory to confirm the answer. Teachers should provide students with several direct questions based on the basic ideas of machines using the recommended methodology. Professors should also conduct simulations and laboratory experiments to verify their findings before presenting them to the class, conceptually evaluate the issues at hand, and then pass the simulation models to students. Teachers spend one to two hours at the beginning of class going over the basics of the approach, how to go about making it a reality, and how to use the Q-NET Mechatronic Actuators board and LabVIEW software. The introduction of LabVIEW and Q-Net is assigned as the bridge course for the 2022 Group 1 of 30 students.

III. PRINCIPLES OF MOTOR, THEIR CONTROL AND EXCITATION MODES, AND QUESTIONS

Using the primary principle of the electric machines, there are three one-of-a-kind sorts of motors which might be studied in this case have a look at- Brushless DC motor, Stepper motors, DC servo motor.
1) Brushless DC motor- The Special DC motor which produce torque by introducing the permanent motor in the rotor and which commutates the three-phase supply using coils/electromagnets in the stator. Brushes are unnecessary to conduct electricity to the rotor, so the absence of brushes naturally leads to a longer life and low sustainable costs. The introduction of Rotor position sensors like rotary encoder, back emf measurements or Hall sensor measurement system is most

commonly used to decide the angular position of the rotor. The position sensors are widely used to identify the positions through proximity switching, current sensing and speed control of Brushless DC motor. Figure 1 shows the circuit required to drive the brushless DC motor.

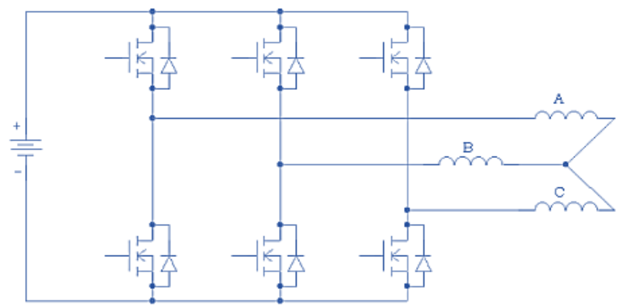


Fig 1: Three half H-bridges required to drive the brushless DC motor

2) Stepper motor- It rotates the armature in discrete steps. The two basic winding configurations for stepper motors are unipolar and bipolar windings. Figure 2 shows the unipolar configuration used by the QNET Mechatronic Actuators. It is rated at 130 ∘C, or 266 ∘F. To protect users from potential burns, it is not energized continuously, and instead uses a pulsed voltage.

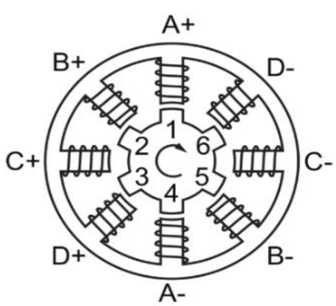


Fig 2: Stepper motor unipolar mode.

3) A DC servo motor or servo is a rotary actuator that uses a feedback sensor to automatically adjust the system's behavior through feedback control. A typical servo consists of a motor, a gearbox, a potentiometer for sensing the angular position, and a control circuit. The servo used on QNET mechatronic actuators is equipped with a 3-5V pulse at 50Hz.

The author asks three questions to help students understand the properties of electrical machines. Students will need to accomplish three types of analysis: theoretical, simulation, and experimental before providing final answers. Working as a team is required of each trio of students. These are the inquiries:

Q1 For the given DC shunt motor which is selected as a generator set of operating voltage 250V at the rate of 800 rpm on no load. The armature resistance of 50 Ω and the field resistance of 250 Ω respectively. If the motor running as the no load machine at 4A and 250V. Calculate the velocity and performances of the system which running as motor drive at 20A at 250V.

Q2 Select a suitable low-cost special open-loop machine for automating an industrial conveyor control system in a water bottle manufacturing application and explain its construction and working principle with a clear diagram.

Q3 Illustrate the stepper motor static characteristics and dynamic characteristics with 16 stator teeth and 4 rotor teeth. Find the step angle and step speed respectively.

Earlier the "Experiments with electrical machines" course, the teacher arranged a preview. Its content was to repeat the basic principles of the electric motors in the course of electrical machines and answer three given questions (Q1, Q2 and Q3). Theoretical analysis showed that 5 out of 24 groups (20.8%) answered question Q1 correctly and 8 out of 24 groups (33.3%) answered question Q2 correctly.

Low accuracy rates may be due to students lack of understanding of basic concepts or their inability to engage in active learning as they waited for the teacher's answer to the questions posed. Therefore, the authors propose a method involving theoretical analysis, simulation, and experiment. The desired outcome is to provide students with the opportunity to actively search for solutions and practice problem-solving skills.

IV. THEORETICAL ANALYSIS OF PROPOSED WORK

A theoretical analysis is presented to answer the question. No-load speed is defined as a reference to how fast the motor shaft will rotate before weight is added to it. When the given armature coil conductor of DC motor conduct current in the existence of the stator field flux, creating a mechanical torque between the armature and stator winding. The generated torque is calculated by the development of force and the circumference of the shaft head. Mechanical power developed by the motor is given by

$$Pm = Eb \times Ia \qquad (1)$$

Eb is EMF developed and Ia is armature current

In terms of torque and speed mechanical power developed is given by

$$Pm = \text{torque} \times \text{speed}. \qquad (2)$$

Speed is in radians per second (ω).

$$\omega = 2\pi N/60 \qquad (3)$$

In a DC shunt motor, the back emf is given by

$$Eb = (NP\varnothing Z)/60A \qquad (4)$$

Where, N is the speed, ϕ is the flux per pole, P is the number of poles, Z is the number of conductors

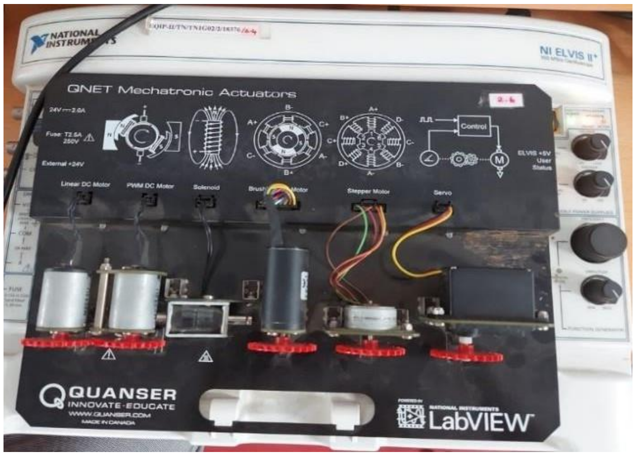


Fig 3: Experimental Setup- Q-NET Actuators Board

A PLC can be used to set up a slight and modest filling system. The conveyor motor belt is used to move the motor. A DC pump is built into the tank to control the flow of water. A Proximity sensor senses the position of the bottle and then start pump the motor. The advantages of using SPS are smooth operation, low cost and high filling speed. In order to improve substantial speed, PLC should be used in the automatic filling system. The process is controlled by ladder logic.

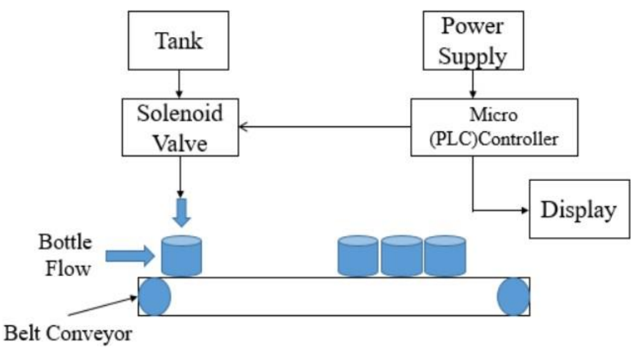


Fig 4: Flowchart for Assembly of filling machine

For a simple automatic water filling system, a brushless DC motor, also called a synchronous motor, is used to manually control the speed. It is powered with the aid of direct contemporary ampere that is inverted from alternating modern-day with the aid of an inverter. The advantages of this engine are excessive pace, electric control, and so forth. Stepper motor characteristics are divided into two groups

- Static characteristics of operation
- Dynamic characteristics of operation

A stepper motor is a special step operated open loop motor is said to be operated synchronously with one-to-one correspondence between the No. of pulse rate carried out and the No. of steps the motor has clearly moved. A stepper motor is a open loop control motor which exited the winding for clock wise and counter clock wise using full step or half step program method. Thus, the stator windings are energized using pulse train signal as input for discrete angular rotation as output connected with application. The step attitude is described because the perspective by using which the stepper motor shaft rotates for every command pulse. It's far denoted as β.

$$\text{step angle } (\beta) = ((Ns-Nr)/(Ns*Nr)) *360 \qquad (5)$$

Where, Ns – The stator poles or teeth number
Nr – The rotor poles or teeth
number m – stator phase number.

(a)

(b)

Fig 5 (a): Q-NET set up for Stepper motor demonstration and 5(b) Q-NET set up for Brushless DC motor demonstration

In conclusion, it is possible to find solutions to questions Q1, Q2 and Q3 through theoretical analysis and detailed study of machines. Although some minor problems were solved by theoretical analysis, students cannot objectively verify the correctness of the theoretical derivation. Therefore, to answer the problem, students must perform simulation and experimental verification, as well as provide a thorough and reliable technique of theoretical analysis, simulation and experimental verification. To verify the theoretical analysis, the author offers simulation and experimentation.

Students can perform simulations using professor-provided simulation models based on the Q-NET Mechatronic Actuators board and LabVIEW software to verify the answers to the questions as shown in the figure 5(a) and 5(b). Students can also change simulation parameters and do simulations. Circuits for simulating electric motors are displayed in Figure 6, 7, 8 and 9. In Figure 6(a), waveforms of Tooth Sensor Debounced are plotted against time when the step delay is set to 5 milliseconds. In general, jumping is when the output of a sensor, most often on a physical limit switch, bounces from on to off before settling to a single value. The debounce time (in ms) is the time in milliseconds before the sensor state changes to on. And motor current is plotted against time. In a stepper motor, the torque delivery is proportional to the current directly flowing through the motor winding: the higher the current, the higher the torque delivered by the motor. In Figure 6(b), the step delay is changed to 10 milliseconds and the stepper motor graph is observed.

In Figure 7, the waveforms of motor speed and Motor Current are plotted for a Brushless DC motor. Here, we exchange the PWM responsibility cycles to create sinusoidal alerts. The pulse width of signal generation methods is widely used in the BLDC motor control using LabVIEW and corresponding LABVIEW circuit for stepper motor and servo motor are shown in figure 10 (a) and (b). Control circuits for brushless sinusoidal motors typically use pulse width modulation (PWM). This facilitates regulation of the current injected into the rotor windings, making the commutation technique run smoother and more effectively. This is especially true for closed-loop controllers that receive feedback about the output signal and change the input strength across loops with different responsibilities. PWM switching frequency may vary from application to application. Although it should be tall enough to avoid it. In Figure 7, waveforms of speed (in rps) and fundamental currents (mA) are plotted for a Servo Motor by varying the Servo pulse width. Servos are controlled by pulse width; the pulse width determines the angle of the horn. Every 10 µs increase in pulse width typically moves the servo 1 degree more clockwise. Pulse width modulation is used in various applications, especially for control. The use of servo motors to drive pump motor is rapidly gaining aggradation and is now being used by many manufacturers due to the recent price drop in servo motors. These are typically lever-type clamping machines that use a servo motor as a variable speed drive for a fixed displacement pump (both piston and gear pumps are used). For a typical servo motor rotating 180 degrees, a pulse width of 1 ms drives the shaft to 0°, 1.5 ms to 90°, and 2 ms to 180°.

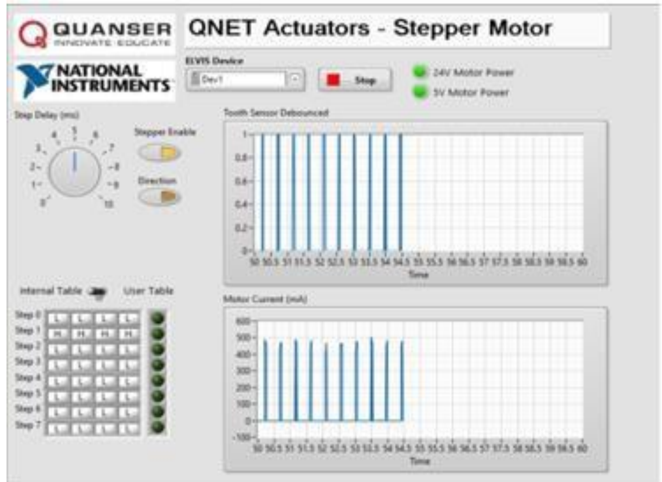


Fig 6a. Experimental waveforms of Tooth Sensor Debounced and Motor Current (mA) of Stepper Motor: When step delay is 5 ms.

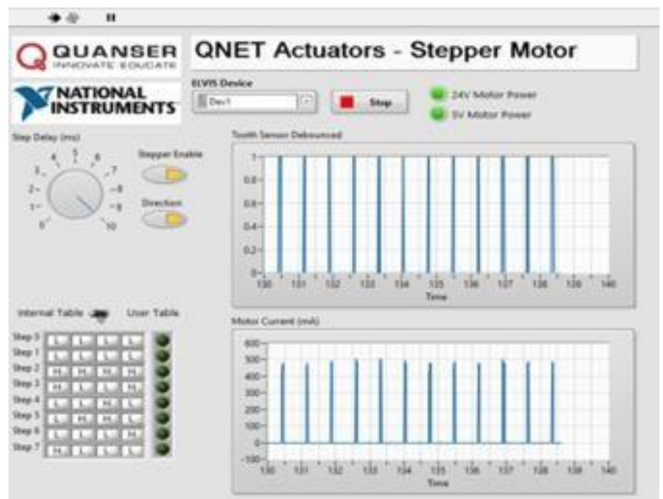


Fig 6b. Experimental waveforms of Tooth Sensor Debounced and Motor Current (mA) of Stepper Motor: When step delay is 10 ms.

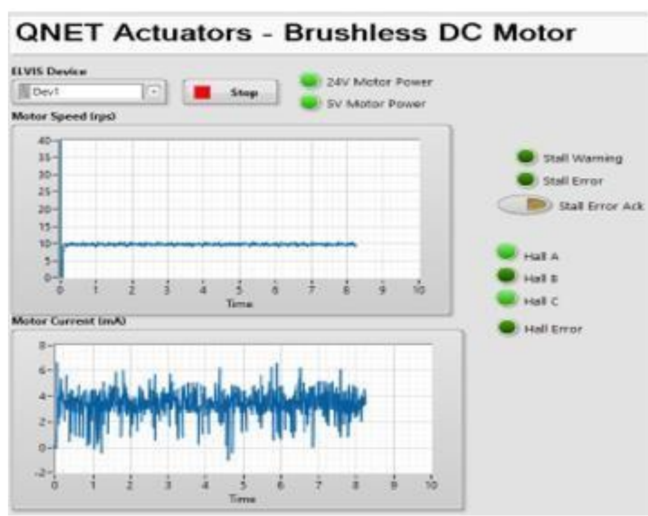


Fig 7: Simulation waveforms of motor speed(rpm) and Motor Current(mA) in Brushless DC Motor.

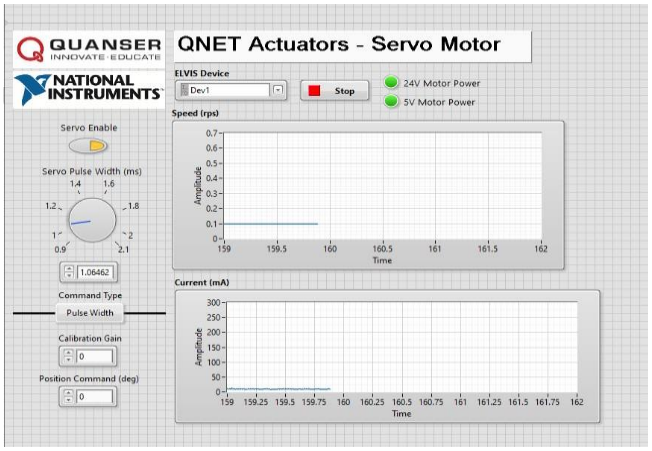


Fig 8: Experimental waveforms of speed (in rps) and fundamental currents (mA): (a) when Pulse Width is 1.06 ms

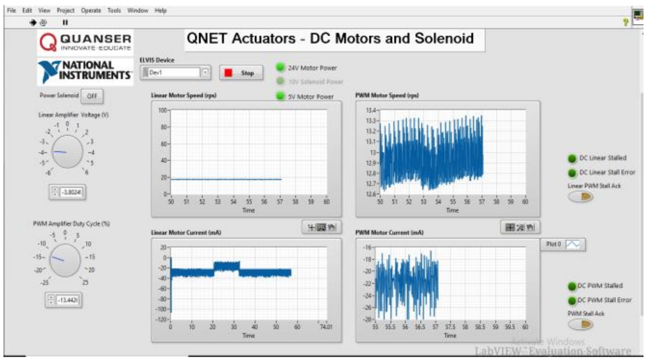
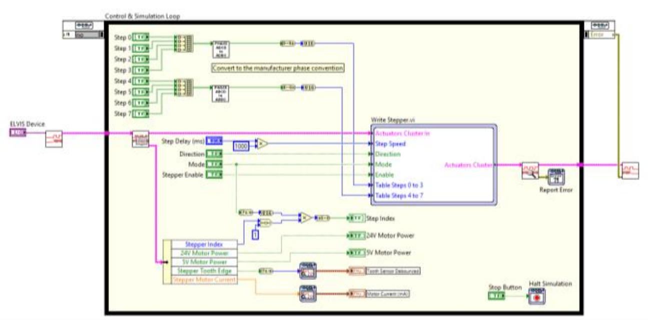
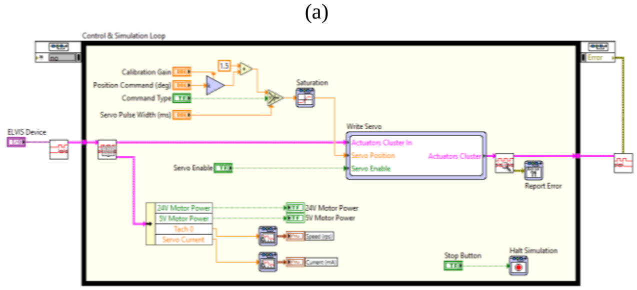


Fig 9: Experimental waveforms of speed (in rps) and fundamental currents (mA): when PWM amplification duty cycle is -13% and linear voltage -3.8V



(a)



(b)

Fig 10: Experimental LABVIEW Circuit for (a) Stepper motor and (b) Servo motor

V. RESULTS AND STATISTICAL ANALYSIS

The writer conducts a questionnaire survey of the students and assesses the effectiveness of the suggested small-hassle-primarily based teaching approach. The cause of Questions Q1, Q2 and Q3 is primarily to decide whether the technique defined on this paper is effective.

Inquiry into college students hobby within the proposed approach and its applicability is the primary goal of the questions. diverse styles of solutions have been acquired in the long run of the experimentation technique.

I think that my problems have been solved through theoretical analysis, simulation analysis and experimental verification.

- I believe that the method of theoretical analysis, Simulation analysis and experimental verification are useful for solving problems.
- I contemplate that the teaching method based on small problems is an effective method of learning.
- I believe that in the future I will solve the challenges in the course using the methods of theoretical analysis, simulation analysis and experimental verification.
- I believe my interest lies in using theoretical analysis, simulation analysis and experimental validation to solve problems related to the course that I do not fully understand.
- I believe that the method of theoretical analysis, simulation analysis and experimental verification is suitable for undergraduates to deal with the difficulties they do not understand in the course.

According to the answers to the questions, we understood that most of the students believe that they have found the solution to the problems and that the author's strategy is effective. Most students will continue to apply the author's question-answering strategy in their future research. Most students are interested in the proposed strategy and believe that it is suitable for college students to solve problems.

According to the findings of the questionnaire, students are interested in the strategy proposed by the author, which indicates that most students will prefer it. Based on questions Q1, Q2 and Q3, the proposed technique performs analysis of simulations, theoretical analysis, and experimental confirmation. The proportion of pupils who respond correctly to the thinking questions can indicate whether the proposed approach is suitable for them. The proposed technique ought to be capable of educate humans a way to resolve troubles on their personal at the same time as maintaining a first rate of accurate responses to the questioning workout. We eventually analyze the responses to 3 queries. An accurate rate of 70.80% was achieved for Q1 by 17 of the 24 groups. The accuracy rate for Q2 was 95.80%, with 23 out of 24 groups providing the correct response. The accuracy rate for Q3 was 90.0%, The accuracy charge was higher after employing the teaching strategy advised here than it had been earlier. The accurate rate established the method's efficacy.

The accurate charge demonstrates that the general public of students can effectively complete theoretical analysis, simulation analysis, or experiment verification. The cautioned method can take a look at students capability for unbiased problem- fixing. Inside the course of the electrical Machines, a proposed Small Problem-Based Teaching Method Using Theoretical Analysis, Simulation Evaluation, and Experimental Verification, can enhance college students ability for independent problem-fixing. although it has a certain impact, the teaching and getting to know content is multiplied. here, the writer conducts a questionnaire survey (Q. 1,2 and 3) to decide how hard the recommended technique is to implement and how to go approximately solving it.

1. We will use theoretical analysis, simulation analysis, and experimental verification methods to solve problems that you do not understand in the course. Is the process difficult?
2. Do simulations and experiments require explanation?

Students responding to question 2 say that suggested method is challenging. This is because stand-alone problem-solving exercises weren't very common in the past. Also, through Question 3, the majority of students ask teachers to explain simulation models and experiments. For this reason, a suitable introduction and explanation must be given in order for students to master the suggested method. The students ability to independently solve problems will be impacted if the introduction and explanation are too detailed. On the way to interpret and make clear that the distinction among the two pattern units (in this case, the effects of college students from internal tests) is because of the actual distinction inside the populace stage and not due to some random mistakes in the evaluation, the proposed work protected two agencies of electrical route samples.

$$t = {(X_1 - X_2)}/{S} \tag{6}$$

The mean of our first set of student results obtained prior to using our tutoring approach is represented by X1 (Batch 1). X2 (Batch 2) is the average of our second set of student results obtained after applying our tutoring model, which enables the tutors to identify the areas in which each student needs to develop.
S – Noise value, X1 – X2 – Signal

The estimated difference in the sample set means for the student's results according to this interpretation is -9.80. Fusic et al. recommended the t test approach for group student comparisons based on confidence intervals in 2022. The proposed work contains intermediate values from -11.35 to -8.04 were used in the computations, with a t value of 9.07 and a standard error of difference of -9.80. The 95 percent confidence interval (ci) for this difference is the same out of 100%. as displayed in Table 1. The null hypothesis in Table 2 result indicates that there is no difference in the mean ratings of the two results. The decision is made to reject the null hypothesis and come to the conclusion that the findings from two internal tests are different and the dataset is valid for our study because the p- value is 0.0001, is less than recommended limit of 0.05.

TABLE 1:
TWO GROUP RESULT OF T TEST

Descriptive Statistics					**Estimation for difference**	
Sample	**N**	**Mean**	**Std. Dev**	**SE Mean**	**SD error Difference**	**95% CI for difference**
Set-1	30	26.45	9.02	1.1	-9.80	(11.35, -8.04)
Set-2	30	37.23	6.32	0.80		

TABLE 2:
T TEST HYPOTHESIS CLASSIFICATION

Null Hypothesis		$\square_0$: $\mu_1 - \mu_2 = 0$
Alternate Hypothesis		$\square_1$: $\mu_1 - \mu_2 \neq 0$
T-Value	**DF**	**P-Value**
-8.04	114	0.0001

VI. CONCLUSION

In the suggested technique, which describes the Q-NET-based experiment approach with the Electric Machines course, the author provides a small-problem-based learning approach that will help students become more adept at solving problems on their own. Three issues about electrical machines—the stepper motor, the servo motor, and the brushless DC motor—can be answered by students by employing a demonstration-based small problem technique in conjunction with traditional approaches like theoretical, problem, and product approaches. Most students are able to find the correct response to the list of questions using the suggested method, which is effective. Students that successfully complete simulations and experiments accurately respond to the question. The survey findings confirm the viability of the suggested strategy. The suggested strategy will assist pupils in improving their problem-solving skills on their own. The majority of students found the concept intriguing and agree that it is crucial for college students. They'll continue using the advised methods in their subsequent studies. The teacher should provide a proper introduction and explanation at the start of the recommended technique. Introductions and explanations should be succinct and straightforward in order to avoid hindering students' abilities to solve problems on their own.

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