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PAPER

Revolutionizing Engineering Education: Exploring Experimental Video-on-Demand for Learning

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ABSTRACT

Attention to the interaction between instructors and students in engineering education is of remarkable importance. Incorporating practical work alongside theoretical teachings can enhance the effectiveness of learning. In this article, the use of short video-on-demand is introduced as a method of teaching students. An experimental video sample is used, and the interaction between the instructor and students in the classroom while using this video is discussed. As a case study, we investigate the concept of periodic waveforms in a stable system and multi-periodic waveforms in an unstable system, resulting from a change in a control parameter. Although the work is demonstrated on a specific scientific topic, the suggested method can be applied to other scientific subjects. In order to enhance the effectiveness of education, tasks outside the classroom are assigned in addition to in-class activities. The proposed method has been implemented during several academic semesters at the undergraduate and graduate levels, specifically in the fields of mechanical engineering and renewable energy engineering. The results obtained from surveys and evaluations indicate a strong connection with students, understanding and retention of scientific topics. One of the significant advantages of the proposed method is the visualization of educational content through short videos, which enhances the learning process. Among the findings of this study, improvements in skills such as accuracy and the application of engineering reasoning, in addition to scientific knowledge, can be highlighted.

KEYWORDS

T-periodic, stability, current controller, engineering education, active learning

1 INTRODUCTION

A system, including a converter and its controller, can operate in different operating zones, such as T-periodic and multi-periodic [1–6]. To analyze the stable and unstable regions of a system, bifurcation diagrams can be plotted [5–6]. The bifurcation diagrams present the variation of the system variables as a function of the bifurcation parameter. The physical systems or controller parameters can be considered bifurcation parameters [7–8]. The different types of bifurcation may occur [9–10].

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A review of the literature reveals various proposed techniques for engineering education. Using the story, graphical abstracts, pictures, and scientific points can be introduced [11–15]. In [15], images were used to teach coding and familiarize students with the software environment.

The use of photos or paintings with dialogue and student gestures is employed to introduce scientific concepts and even evaluate students. For younger generations, video is a highly effective medium [16]. In [17], the use of vlogs is an active learning method for students. A game training is investigated in [18]. However, more research is required to determine the precise characteristics of video games.

In [19], gamification is used as a pedagogical strategy to encourage students to work harder. The epistemologies in action are presented in [20]. A robot prototype is introduced for learning in engineering courses [21].

This paper presents a method for teaching students based on experimental tests. A short video is used. The system under study is a DC-DC converter. A modulated hysteresis controller [8] is used to regulate the current in the inductance, as depicted in Figure 1. The state variables of the converter are the input current (i_L) and the output voltage (V_C). The converter components are shown in the block diagram: the inductor (L) and its series resistance (R_L), diode (D), and switch (K). There is a load resistance (R_{ch}) and a capacitor (C) at the output, and the voltage source (V_e) is at the input (Figure 1a).

The hysteresis controller has a band (B_h). A triangular signal (with period T and amplitude 2A) can maintain a constant frequency [22]. The reference to the inductor is i_{ref}. The error is defined as, ε, ($\varepsilon = i_L - i_{ref}$). Using the integrator term, the error surface is defined as, $S = \varepsilon + K_i \int \varepsilon \, dt$. The gain K_i can regulate the controller's bandwidth [9], [23]. To achieve zero error in a steady-state regime, the integrator term is added. The output of the controller is the command signal (u) of the switch (Figure 1b).

The equations of the converter can be expressed as follows:

$$\begin{cases} \dfrac{di_L}{dt} = \dfrac{1}{L}(V_e - R_L i_L - (1-u)v_C) \\ \dfrac{dv_C}{dt} = \dfrac{1}{C}\left((1-u)i_L - \dfrac{v_C}{r_{ch}}\right) \end{cases} \tag{1}$$

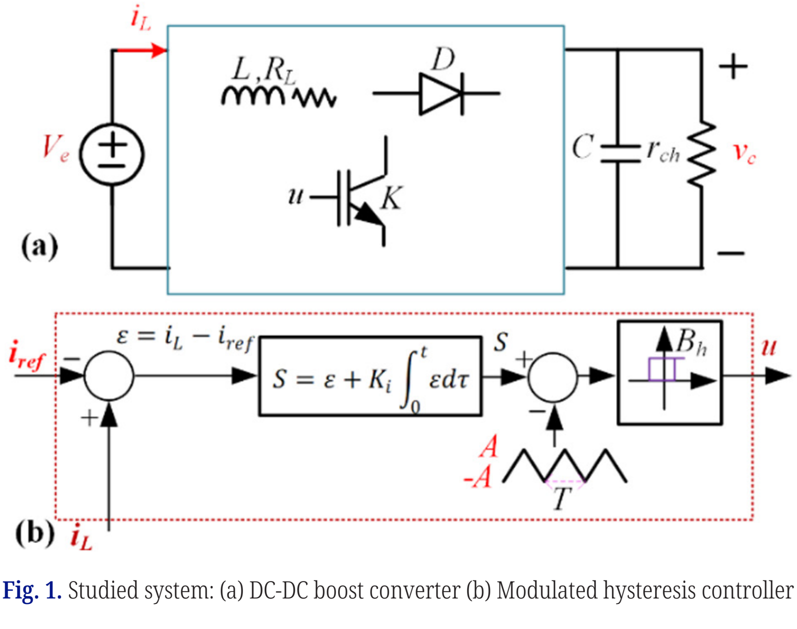

Fig. 1. Studied system: (a) DC-DC boost converter (b) Modulated hysteresis controller

The interaction with students in the classroom is remarkably important. Maintaining student participation and attention in the teaching process requires proper planning. In the proposed teaching process outlined in this article, various methods have been employed to ensure that students' focus is maintained, taking into account their different learning styles in the classroom. Different steps are defined to prepare students' minds for each classroom activity using a laboratory experiment video. Additionally, assignments are introduced outside the classroom to reinforce the topics and receive feedback on the level of understanding. Other ideas for further discussion in the classroom are also presented. Nurturing students' abilities in education and evaluating them is possible. The assessment methods should not only measure students' learning levels but also enhance their skills and attitudes. Examples of such experiences are presented. The results and surveys confirm the effectiveness of using interactive short videos to visualize educational content.

On the other hand, the cost of using laboratory equipment is high, and it may not be feasible to provide laboratory facilities for a large number of students. From this perspective, although the experimental video method is effective, the instructional cost will be low.

The research question is: How can we enhance the effectiveness of the teaching process and facilitate long-lasting learning? The objective of this study is to improve and enhance students' learning by utilizing visual aids to present educational content.

Research assumptions are as follows:

- Based on previous psychological studies on learning, visualization can enhance retention in the learning process.
- Learning conditions are equal for all students. They can participate in classroom discussions and express their opinions.
- Students have the necessary prerequisite knowledge related to the scientific topic.
- Section 2 introduces the suggested idea. This is followed by presenting student responses to an exam and a survey in Sections 3 and 4. The conclusions are presented in Section 5.

2 PROPOSED METHODOLOGY

In this section, the steps followed in the classroom session to implement the suggested idea are shown in Figure 2.

The teaching method utilizes practical videos. The duration of this short video is 48 seconds. Following a discussion on the video and after considering various viewpoints, scientific subjects are taught. The four steps considered include: 1. Individual first impressions, 2. Collective participation, 3. Group exercise, 4. Other ideas after class.

2.1 Step 1: Individual first impressions

The practical video can be presented with or without audio. It can be replayed numerous times. The students can write down the observed points. These points can be listed on the classroom board.

Devices, signals, and various system zones can be discussed.

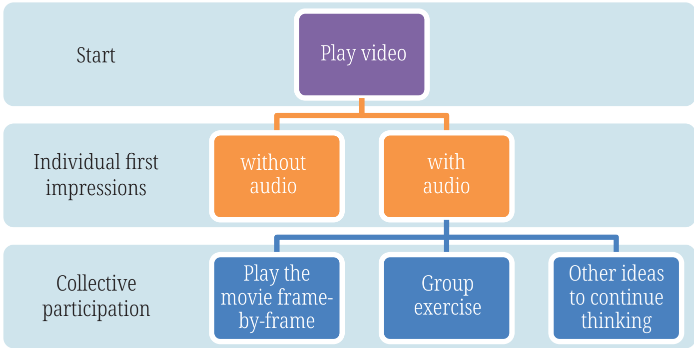

Fig. 2. Process in class

2.2 Step 2: Collective participation

When discussing video playback, the video is paused frame-by-frame, and discussions are conducted. The power supply, as illustrated in Figure 3a, should be identified. By carefully observing, students can become familiar with the components of a power supply and learn the details with their assistance. The voltage and current knobs, pushbuttons, and words such as GEN60-25, as well as the adjusted values, can be used as clues. The device's manual [24] and other related items can be discussed. The multimeter, as shown in Figure 3b, can be discussed as another device in class.

The range selector knob, the multimeter terminals, the unit of measurement displayed on the screen, and its corresponding value provide valuable clues for students. Different models of multimeters can be beneficial for lower-level students [25].

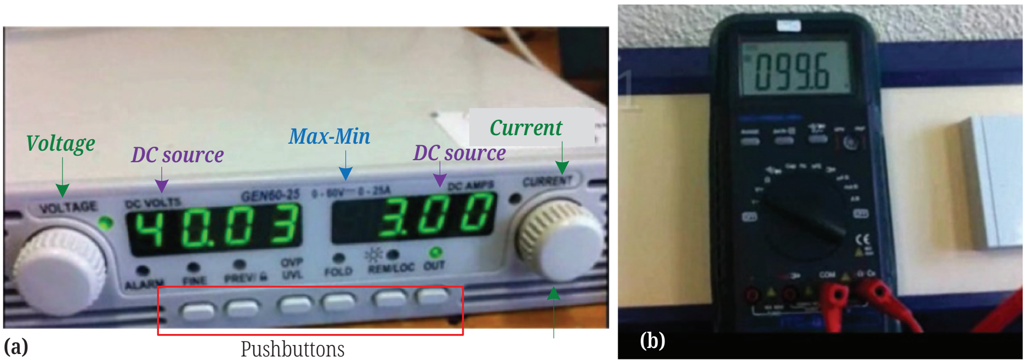

Fig. 3. (a) A programmable DC power supply (b) Voltage of load

Now, the first waveforms displayed by the oscilloscope can be examined in Figure 4 [25]. The colors, such as green, blue, yellow, and purple, and the words ch1, ch2, ch3, and ch4 are clues for the students. With the help of units such as "A" for channel 1, students can guess the waveform of the current for the yellow signal.

The command signal waveform (Channel 3) is determined. Changing the amplitude of this signal to match the requirements of a real switch can be explained [26].

The gain and amplitude of Channel 4 waveforms can be discussed. Establishing a correlation between the values displayed on the power supply or multimeter and the amplitude of the signals can be another topic for class discussion. After identifying the waveform of the capacitor voltage in Channel 2, the command signal in Channel 3, and the waveform of the inductor current in Channel 1, it is time to analyze the last signal in Channel 4. This signal is selected from the control portion of the system to allow the teacher to demonstrate the impact of a control parameter on the system's behavior.

Figure 5 illustrates the behavior of two system state variables in response to variations in one of the control parameters, specifically the amplitude of the triangular waveform. In these examples, the system exhibits multi-periodic behavior.

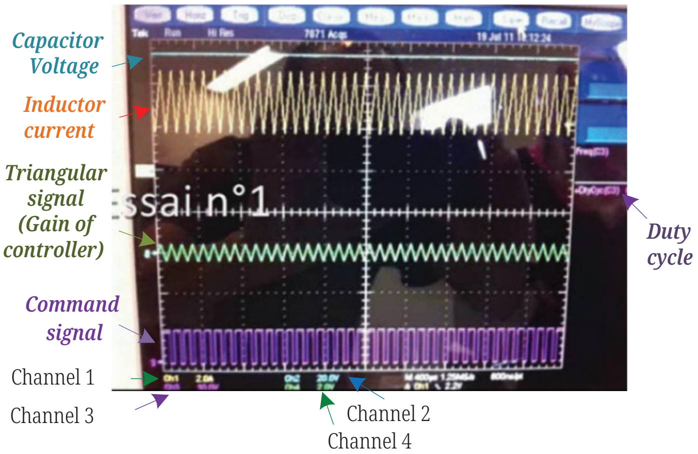

Fig. 4. Inductor current, capacitor voltage, triangular signal, and command signal waveforms, in T-periodic regime (First operating point)

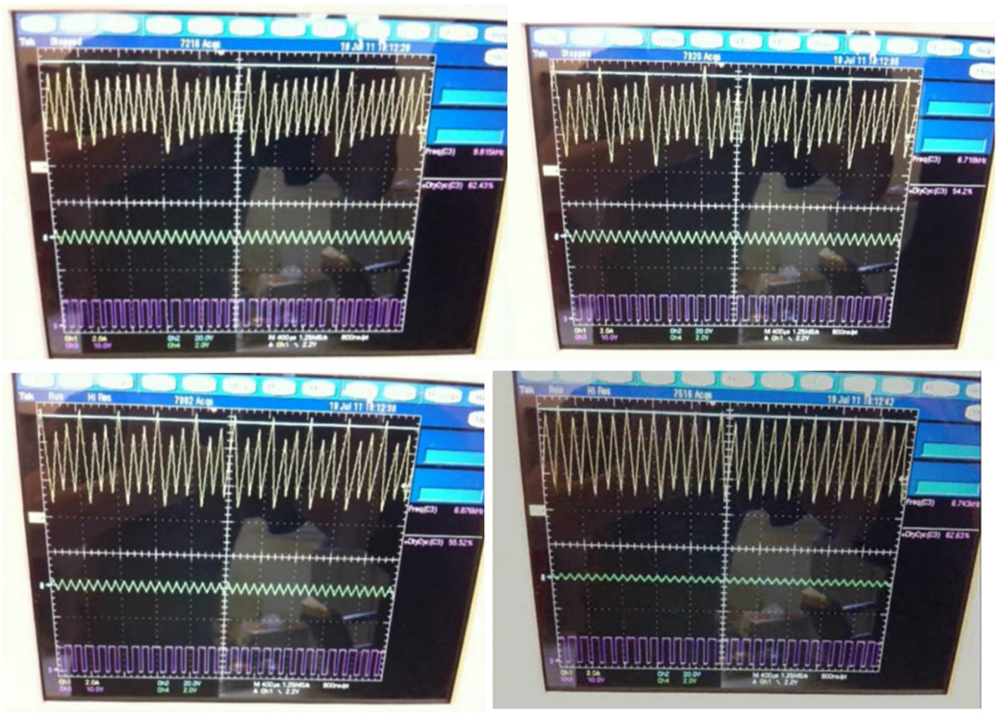

Fig. 5. Inductor current, capacitor voltage, triangular signal, and command signal waveforms, in multi-periodic regime (First operating point)

Now, upon resuming the video, the experiment reveals a shift in the operating point. This is due to the alteration of the load resistance, as depicted in

Figure 6. The value of the load voltage can be seen decreasing, as indicated by the multimeter.

As a first step, students need to understand the purpose of this variation. Apart from changing the load resistance, another existing method for altering the operating point, namely, input voltage variation, can also be discussed.

Then, in the next step, we can discuss the relationship between changes in load resistance and load voltage. Since the system under study only utilizes current control, the output voltage can be decreased by reducing the load resistance.

For undergraduate students, examples of variable resistance loads can be introduced and compared. For example, we can discuss the apparent difference and application of two elements: the rheostat and the potentiometer. The output voltage is approximately 51 V. As with the previous operating point, the desired waveforms on the oscilloscope can be displayed by adjusting the control parameter.

At first glance, it is evident that the amplitude of Channel 2 (capacitor voltage) has decreased, as the origin of the channels on the oscilloscope remains unchanged. Some observant students will notice a change in the gain for Channel 4. In order to enhance clarity when observing and measuring the amplitude of a triangular waveform, Channel 4 is set to one at this stage.

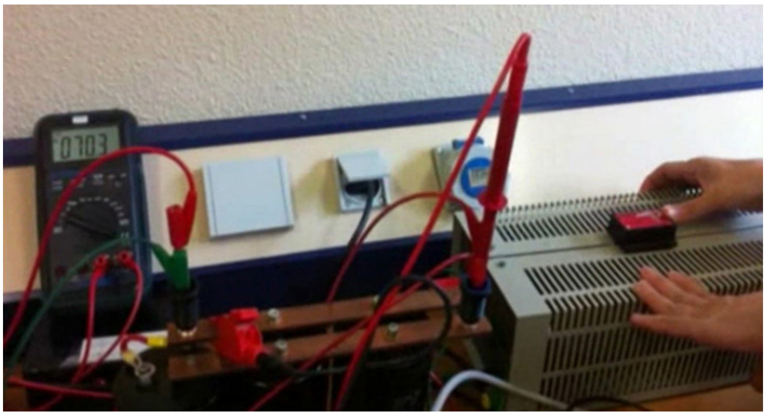

Fig. 6. Change the load resistance to determine the second operating point

We have now assessed the accuracy and inaccuracies of the conjectures made while watching the video. As the video continues, it reveals that by reducing the value of the control parameter, which is the amplitude of the triangular shape of Channel 4, the system transitions from the T-periodic regime to an unstable state. With careful observation, we can note the correlation between increasing the amplitude of the inductor current (the waveform of Channel 1) and increasing the control parameter. However, it is important to note that the appearance of the waveform also undergoes changes. At the end of the video, the relationship between the signals can be summarized.

2.3 Step 3: Group exercise

This project has been conducted over several academic semesters in various classes. The population consisted of approximately 150 engineering students.

A group class activity can be designed to ensure that students have seen the video carefully. Dubbing over the video can be an interesting idea to achieve this goal. To enhance students' creativity and give them freedom of action, the choice of the story topic can be delegated to them. Any subject, ranging from everyday topics to scientific subjects, can be chosen with the consent of the group members. By setting a specific time, each group presents either their live or recorded file.

2.4 Other ideas after class

This issue will be addressed in future sessions to highlight the underlying factors. The structure of the controller can be explained in detail.

Different methods are suggested to obtain feedback on the accuracy and durability of scientific concepts. Some of these can be in the form of homework, while others can be done in the classroom. One of these methods is to display the entire test bench setup. It can be fully represented and discussed with other circuit components.

Another is to show a test bench similar to the one being studied. Waveforms can also be shown for other similar circuits, such as the peak current controller. Students are asked to identify the differences and similarities between waveforms and the system they previously studied.

By identifying the type of converter, we can refer to the start of the video. By taking into account that the current flowing through the source and the inductor is the same, compare the current value indicated by the source with that of the inductor current on the oscilloscope. Students can perform calculations and compare existing values using established theoretical relationships. The simulation results can be compared to the experimental results provided in Section 3.

3 RESULTS

At the end of the semester, during the final exam, one of the questions asked was related to the recall section, as per Bloom's taxonomy. The response time was set at approximately five minutes. The first part was mandatory, and the second part was designed as desired. In this section, we introduce two questions and present the students' answers. The total number of students in this test was 20.

3.1 Question one

Students were asked to write down the goals of working with this short video. Some answers are as follows:

- Familiarity with electrical elements and how they work
- Learn how to display signals on an oscilloscope, including adjusting color and using buttons.
- Familiarity with different regimes, such as T-periodic and multi-periodic regimes
- Familiarity with the control section settings
- Listen to the sound of electrical circuits.
- Explore the impact of parameters on the sound of signals and waveforms.
- See how a complete laboratory circuit is connected, arranged, and operated.
- Accuracy (e.g., color of signals) and precision
- Engraving content in students' minds (like comparing an element to an animal!)
- Utilizing a tool for various purposes
- Familiarity with the class atmosphere, how it works, and class participation
- Application of different elements and tools in practice (such as multimeters and variable resistance)

- Enhance creativity by telling a story on video and voice acting.
- Sometimes, expressing ideas within a framework can be much more effective. The constitutions of the world exist in the nature of various phenomena. Discipline is evident even in disorder.
- Silent playback initially helps with video capture.
- Taking notes and checking threads
- Explore numerous rules presented in the form of easy-to-follow videos accompanied by visual aids.
- Practice teamwork.
- Communication among clues
- Helping to strengthen the engineering vision
- Check the current and voltage in the circuit by varying different parameters.
- Skills to apply information effectively
- Recalling scientific points that we already knew and learning new things by looking closely and having clues.
- Knowing that there is a factor behind the scenes affected our attitude, as we believed that there was something important at play.
- Get feedback on who has already read the class references folder.
- Learn how to design questions correctly.
- Strengthening concentration
- Enhance the art of expression and improve the content related to video in-class practice.
- Pay attention to detail and small-scale reviews.
- Understanding the concept of stability and instability
- Familiarity with the bifurcation diagram and the bifurcation point is important.
- Familiarity with the command signal is important.
- Comparing theory with practice and exploring the differences between these two approaches

The students' answers have been evaluated based on the educational objectives, and the results are presented in Figure 7. It was found that 27% of the students provided excellent answers. 40% of them provided a good answer, while 27% had a satisfactory answer. In summary, students have had a satisfactory learning experience in this subject.

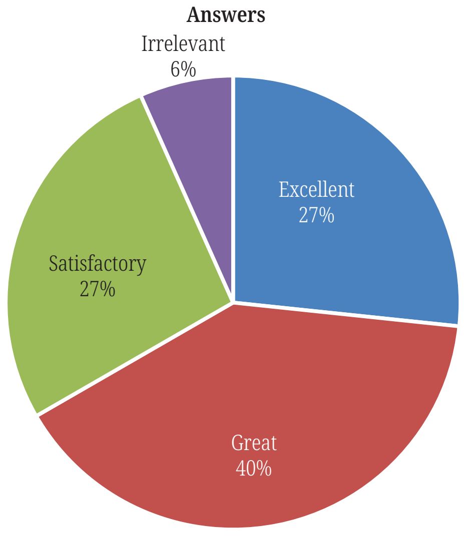

Fig. 7. Percentage of students' qualitative answers to question 1 in the exam

3.2 Question two

In the second question, students were asked to provide ideas for furthering the experiment. The suggested ideas are as follows:

- Practical work with an oscilloscope
- State the objectives of the experiment, and then have students explain how to achieve the requirements of the experiment.
- Before showing the video, it is important to display an oscilloscope and encourage students to share their diverse perceptions and opinions. Students should be grouped and shown a video. Then they should be asked to describe it to the other members.
- Come and see the circuit and work with it in person.
- Comparison of this electrical system with other systems, such as mechanical, chemical, or other cases.
- Play the movie in reverse, starting from the end and going back to the beginning!
- Measure other parameters and become more familiar with the concept of measurement.
- The four signals mentioned can serve as clues to guide further discussions in the upcoming sessions.
- This is an expression of industrial applications used to verify the stability of signals.
- One could use a video like this throughout the semester for various topics, where the elements interact with each other and engage with the students' voices. This approach greatly enhances the learning experience.
- Instead of using photos to introduce electric elements, use this video to introduce tangible elements.
- This movie can be performed as a class play. Each person has an undisclosed identity so that, at the end of the video, the other students can guess which element each person represents. In the next step, the student can introduce themselves and explain more about how it works.
- Identify the common elements between the previous file and this video, introducing those elements.
- Understanding the concepts of life is not the same. This video can also be used as a tutorial for laboratory lessons.

3.3 Student performance

By examining the answers from the first part, it can be seen that the students have a good understanding of the points discussed in this video. Some of these answers have focused on the theoretical aspect and have mentioned scientific concepts and issues. The use of devices, engineering reasoning, and validation are among the cases in this field. Some answers have referred to attitudes such as precision, depth, and attention to detail. Due to the fact that categorizing scientific materials falls under the second category of Bloom's learning theory pyramid, students have been able to comprehend the lesson using this method.

According to Bloom's pyramid, the second question is at a higher level of cognitive understanding. To suggest the continuation of a work, one must have good mental organization. According to the responses received, the majority of students have successfully completed this step and have offered suitable suggestions.

During the academic year, class tests and assignments include questions that assess the higher levels of Bloom's theory. The scores of all students were average to high, and they passed these sections. Two assignments can be mentioned among them. These assignments have assessed the application and analysis of learning. These two sample assignments were:

- Write down wishes and prayers using the scientific materials discussed (elements and signals).
- After watching the video "Story of Signals," generate five original and creative questions that have not been discussed in class.
  Correct and creative answers were received from students for both questions.

3.4 Summary and discussion

Different tasks can be divided according to various perspectives. The activity can be categorized based on whether it is being done by an individual or a group, as well as where it takes place (Figure 8).

From another perspective, the activities performed can be as follows:

Accuracy in observation and curiosity: Accuracy in various dimensions, such as observing the appearance of objects (in terms of color, size, and components), can enhance the engineering vision.

Relationship and connection between components: By carefully observing and establishing communication between different kinds of knowledge, new topics can be realized.

Special questions and motivation to continue: Asking thought-provoking questions that students are not often asked in class and that necessitate a comprehensive search can serve as an incentive to persist in their work. Questions such as: Why can't an ohmmeter be used in the test circuit? Can the appearance of the wave be periodically recognizable? If not, what parameter is required to have a value? How can it be proven that the circuit is on?

Enhanced abilities: This includes proficient searching, effective teamwork, innovative thinking, and a strong understanding of scientific topics such as electrical components, various operational modes, laboratory protocols, control panel configurations, and measurements.

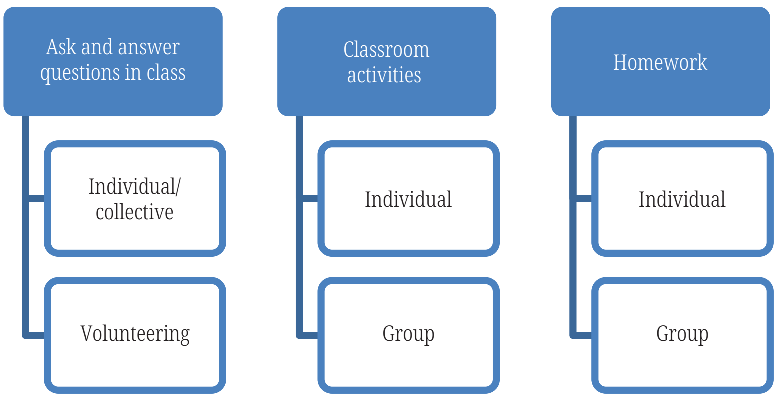

Fig. 8. Different practices inside and outside the classroom

4 SURVEY

In this section, the survey questions for students and the corresponding results are introduced.

4.1 Items and dimensions

The survey included 25 items and five dimensions. The Likert scale was selected for the survey (1 = totally disagree, 5 = totally agree). Cronbach's alpha is selected to measure the reliability of the survey items. The Cronbach's alpha obtained from 37 students is 0.9. The obtained Cronbach alpha indicates that the survey is reliable. The validity of the survey has been confirmed by experts.

Table 1 presents the survey items and their corresponding dimensions. The research population consists of students studying mechanical and renewable energy engineering. Thirty-seven students participated in the survey. Based on the formula mentioned in [27], the number of participants is sufficient to represent the population. The demographic characteristics of the participants are presented in Table 2.

Table 1. Items and dimensions of the survey

Dimensions	N	Item
1. Recognize the laboratory equipment	1	A video clip, along with class discussions, will familiarize you with the appearance of the power source.
	2	A video clips, along with class discussions, will help familiarize with the operation of the oscilloscope.
	3	A video clips, along with class discussions, will help familiarize you with the operation of the multimeter.
	4	A video clip with the help of class discussions, will introduce one of the applications of variable resistance.
	5	A video clips, along with class discussions, will help you become familiar with the connection between devices.
	6	A video clip, along with class discussions, the help of class discussions will draw your attention to the sounds produced in the system being studied.
2. Cognition and behavior changes of signals	7	A video clip, with the help of class discussions, will introduce some important signals in a DC converter.
	8	A video clip, along with class discussions, will help you become familiar with adjusting the control component of the mentioned system.
	9	A video clips, along with the help of class discussions will introduce the command signal.
	10	A video clip with the help of class discussions will make you familiarize with system state variables.
3. Relation of signals with each other and other components	11	A video clip with the help of class discussions can be an introduction to the bifurcation diagram.
	12	A video clip with the help of class discussions will make you familiarize with the point of bifurcation.
	13	A video clip with the help of class discussions will introduce the concept of stability and instability in the studied system.

(Continued)

Table 1. Items and dimensions of the survey *(Continued)*

Dimensions	N	Item
4. Operating points	14	A video clip with the help of class discussions will introduce periodic and nonperiodic waveforms.
	15	A video clip with the help of class discussions will make you familiarize with the operating points.
	16	A video clip with the help of class discussions will make you familiarize with the changing operating points.
	17	A video clip with the help of class discussions will introduce the effects of changes in the operating points on the form of state variable waveforms.
	18	Sound changes in stable and unstable modes are instructive.
	19	Playing the video clip silently at first helps to preview the video clip.
5. Evaluation	20	This method makes educational concepts long-lasting in the mind.
	21	This method is educationally attractive to the students.
	22	How do you rate the effectiveness of this method in recognizing devices? (1 to 5)
	23	How do you rate the effectiveness of this method in recognizing and changing the behavior of signals? (1 to 5)
	24	How do you rate the effectiveness of this method in recognizing and changing operating points mode? (1 to 5)
	25	How do you rate the effectiveness of this method in understanding the relationship between signals and other components? (1 to 5)

Table 2. Demographic characteristics of the participants

Variable		Frequency	Frequency Percentage
Papulation		37	100%
Educational level	Bachelor	27	73%
	Master of Science	6	16%
	Ph.D.	4	11%
Field of study	Mechanical engineering	27	73%
	Renewable energy	10	27%
Gender	Male	24	65%
	Female	13	35%

4.2 Statistical analysis

The data are analyzed with SPSS 15. The Wilcoxon test [28–29], which is a non-parametric test, is selected to analyze the responses. Table 3 presents the hypotheses considered in the paper. Based on the Wilcoxon test, if the statistical significance is above 0.05, the null hypothesis is rejected. The results of the Wilcoxon test are explained in this section. Statistical significance and frequency percentages are discussed for each dimension and item.

Table 3. Wilcoxon hypothesis

Hypothesis	Description
H0	Median equals 3
H1	Median does not equal 3

Dimension 1. The level of knowledge of the participants regarding the laboratory equipment is examined in dimension 1. The details of the Wilcoxon test for dimension 1 are introduced in Table 4. Based on the obtained statistical significance, the null hypothesis for all of the items in dimension 1 is rejected. It means the participant's response is the opposite of "I have no opinion." Figure 9 illustrates the students' responses to the items in dimension 1.

Based on the results, it can be concluded that students, with the help of this method, have become familiar with the performance of an oscilloscope and multimeter, the appearance of a power supply, and one of the applications of variable resistance. This method also familiarizes students with the interconnection of devices and enhances accuracy in creating sounds. Considering the good performance of the mentioned method in understanding the discussed aspects, it has proven effective in achieving the expected learning outcomes.

Table 4. Wilcoxon statistical significance of dimension 1

Item number	1	2	3	4	5	6
Statistical significance	0.00	0.00	0.00	0.00	0.00	0.00

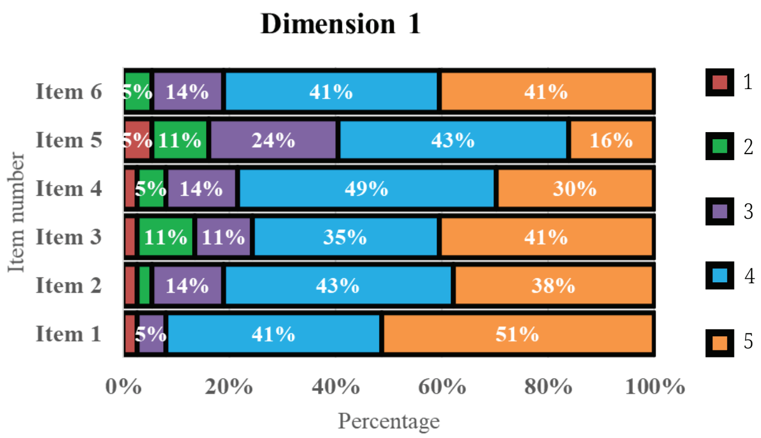

Fig. 9. Detailed of participants' responses to items in dimension 1

Dimension 2. Dimension 2 analyzes cognition and behavioral changes in the signals. The statistical significance of the Wilcoxon test is presented in Table 5. According to Table 5, only item 8 failed to reject the null hypothesis. This shows that the concepts of control in the video clip are not clear to students. This conclusion is accurate because the subject was not yet taught during the survey. Figure 10 represents the response of students to the items in dimension 2. By analyzing other items in this dimension, it can be seen that this method has performed well in the field of understanding command signals and system state variables in a DC electrical converter. The survey results were presented to the students. Based on the results, the students reviewed what they did not understand well.

Table 5. Wilcoxon statistical significance of dimension 2

Item number	7	8	9	10
Statistical significance	0.00	0.78	0.00	0.00

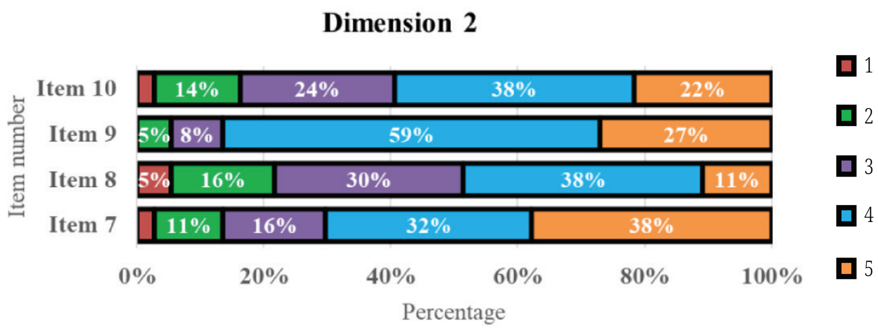

Fig. 10. Detailed of the participants' responses to items in dimension 2

Dimension 3. Dimension 3 researches the communication of signals among themselves and with other components. The results of the Wilcoxon test are shown in Table 6. Items 11 and 12 retained the null hypotheses. The concepts of bifurcation in video clips are not clear to students. At the time of the survey, this subject had not yet been taught to students. Figure 11 shows the percentage frequency of responses to the items in dimension 3. Item 13 evaluates the concepts of system stability and instability. The results obtained from this study indicate that the concept has been effectively conveyed to students through this teaching method.

Table 6. Wilcoxon statistical significance of dimension 3

Item number	11	12	13
Statistical significance	0.25	0.88	0.01

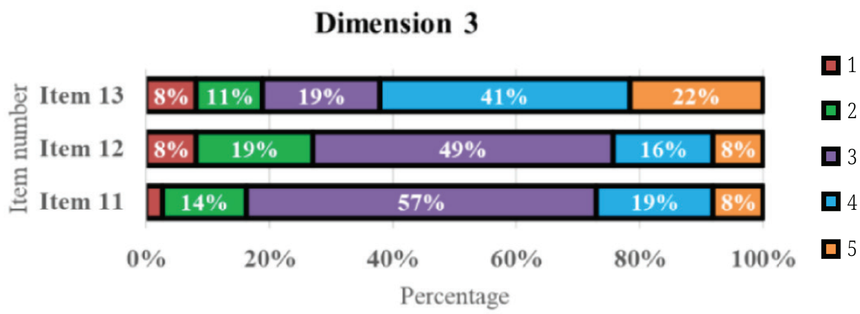

Fig. 11. Detailed of the participants' responses the items in dimension 3

Dimension 4. The concepts of the operating point are investigated in dimension 4. According to the results of the Wilcoxon test, items 15 and 16 did not reject the null hypothesis. Based on the results, the students did not grasp the concepts of the operating point. Table 7 represents the details of the students' responses to the items in dimension 4. Figure 12 shows the frequency percentages of the responses to dimension 4. The results show that students have been properly introduced to the concepts of periodic waveforms and multi-periodic waveforms with the help of this method. Additionally, the change in sound between stable and unstable states has been informative for students. Initially, playing the video without sound assists in visual comprehension.

Table 7. Wilcoxon statistical significance of dimension 4

Item number	14	15	16	17	18	19
Statistical significance	0.00	0.08	0.17	0.02	0.00	0.00

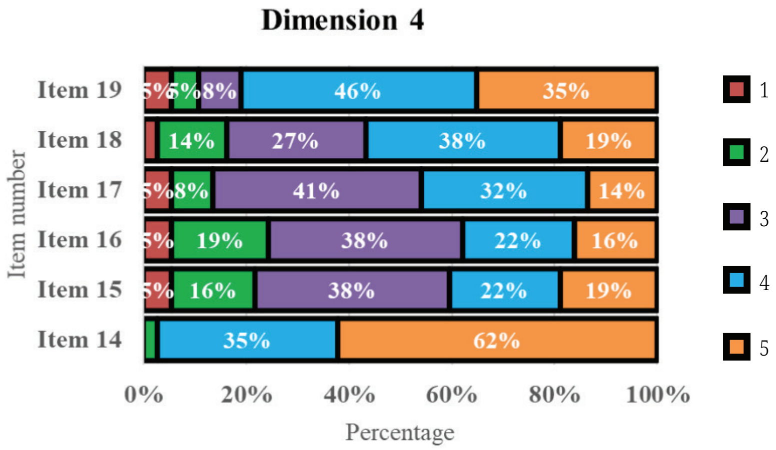

Fig. 12. Detailed of the participants' responses to items in dimension 4

Dimension 5. The evaluation of various aspects of the survey was conducted in dimension 5. Table 8 provides details of the average scores obtained from students. Based on the average points obtained, all of the evaluated aspects scored above 3. It means that the students believed these aspects could be effective. Item number 24 has a lower average score. The students believed that this method was less effective in the cognition of operating point concepts. In addition, students believe that this method can make education more attractive and long-lasting in their minds. Figure 13 illustrates the percentage of responses by frequency to dimension 5. Furthermore, based on the students' feedback, this method has proven to be effective in comprehending the interconnection of signals and other components, as well as in recognizing and interpreting the behaviors of signals and laboratory devices.

Table 8. Wilcoxon statistical significance of dimension 5

Item number	20	21	22	23	24	25
Average	4.35	4.16	3.84	3.92	3.35	3.68

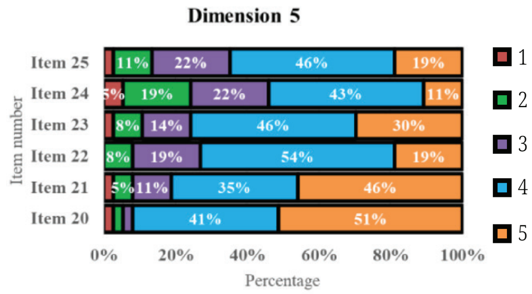

Fig. 13. Detailed of the participants' responses to items in dimension 5

5 CONCLUSIONS AND DISCUSSION

The objective of this paper was to promote students' learning through the use of visual educational content. Using videos is an energetic activity for students in class. A basic and essential topic is students' familiarity with practical work.

The concepts of T-periodic and multi-periodic regimes in an electrical system become apparent through a short video. A DC-DC boost converter and its controller are being studied. This study examined a total of four waveforms. Two state variables, including the inductor current and capacitor voltage, are parameter of the modulated-hysteresis current controller and the command signal for the switch of this converter. At several operating points, some tests are conducted in different operating zones of the studied system, such as T-periodic and multi-periodic tests, to observe the effects of changing a control parameter.

Different activities and homework assignments are defined as individual or group work. The proposed method can help the student learn and absorb the desired scientific content. Figure 14 shows some achievements regarding students' familiarity with scientific concepts. Through these achievements, students can gain a good understanding of the devices used on the laboratory test bench and become familiar with waveforms.

At a higher level, they find a complete connection between all the components with the help of hearing and vision. Communication between signals, working conditions, and control parameters are examples of visual components. Paying attention to how the sound of the movie changes in different modes is an example of the listening component. Some points can be given as feedback to students to enhance the accuracy of their observations as much as possible. The fact that some students have paid attention to the color or the formatting in different sections of their answers is an example of their accuracy (Figure 15). Designing assignments outside the classroom, along with activities and participation in the classroom, can ensure that the desired scientific content is retained in the students' minds.

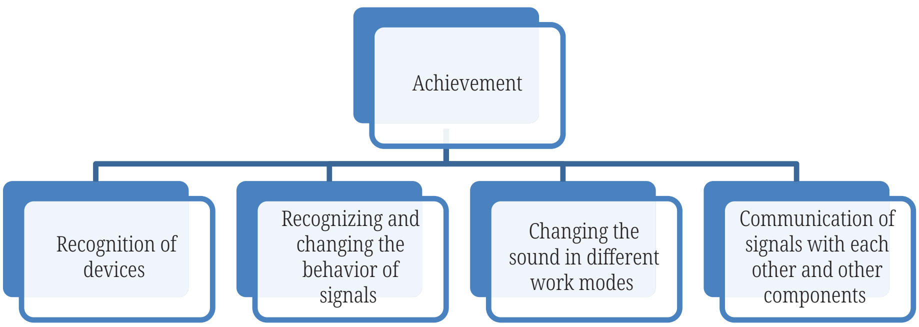

Fig. 14. Some achievements from the laboratory short video review

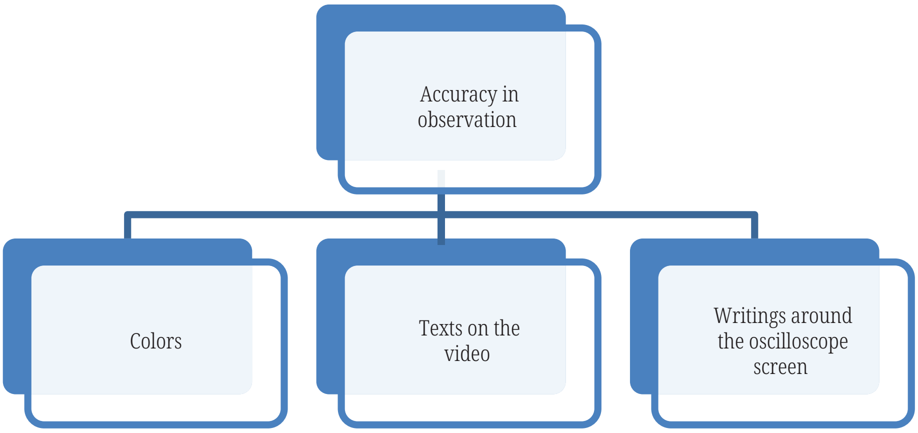

Fig. 15. Giving feedback to students to strengthen the accuracy of observation

Among the findings of this method are enhanced abilities, including effective search techniques, teamwork, creativity, and familiarity with scientific topics such as electrical components, various operational modes, laboratory equipment, control panel configurations, and measurements. The students' fields of study were renewable energy engineering and mechanical engineering. According to the analysis of students' test and assignment answers, as well as their grades over a six-year period, it is evident that the interactive method of introducing videos was effective. In addition, students have developed a strong rapport with this method.

The Wilcoxon test is used to analyze the data obtained from the survey regarding the proposed method. Based on the results, the proposed method makes education more attractive and long-lasting. This method can also be used to review the materials that have been learned. The instructor can assess whether students have understood all the presented points based on the video content and provide further explanations for topics that were not clear to the students during the teaching process.

The effectiveness of the proposed method has been examined from various perspectives. According to the results, this method has proven to be effective in achieving the expected learning outcomes related to students' comprehension of various aspects. The instructor's expected learning outcomes for different levels can be categorized. For example, introducing students to the appearance of a laboratory instrument is an introductory level of learning, while acquainting them with a deep scientific concept is an advanced level of learning.

Some criteria received lower scores compared to others. The reason behind this is that the discussed topics were not thoroughly examined during the survey.

In summary, it can be inferred that this method has been effective in understanding various aspects. The exercises were effective in providing additional practice for comprehending the relevant concepts taught by the instructor. Additionally, other skills were strengthened, such as students' initiative in group collaboration.

Visualizing educational content through interactive short videos plays a significant role in facilitating effective learning. The test results confirm the effectiveness of the proposed method.

The instructor was able to utilize short instructional videos at each level and deliver content ranging from basic to advanced, depending on the students' comprehension.

The proposed method has been demonstrated for a scientific topic, but this concept can be applied to teaching other scientific concepts through the creation of short videos.

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