Solution-oriented teaching method of electric power circuit design for online on-demand video streaming lecture course

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Solution-Oriented Teaching Method of Electric Power Circuit Design for Online On-demand Video Streaming Lecture Course

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***Abstract*—The on-demand video streaming lecture courses are recently spreading in the industrial electronics education programs to offer time flexibility to students of various affiliations and professions. However, this style of lecture course tends to lack real-time communication and feedback from the students, which makes it difficult for the teachers to orient the students' attention to the topics of the lecture. This paper addresses this difficulty in the field of power electronics by proposing a teaching method for the on-demand video streaming lecture course on practical electric power circuit design. In this method, the education video of each class presents an experiment of an actual electric power circuit and then assigns the report proposing the best design for the homework. By sharing the practical design considerations among the students, this method encourages the students to imagine the professional work of the circuit design engineers and to learn the professional circuit design skill. Along with the basic concept of this teaching method, this paper also presents an actual teaching course designed according to the teaching method as well as the students' impressions answered by the questionnaire survey. The majority of the students agreed on the positive effect of this teaching method to motivate the students, suggesting the effectiveness of this teaching method.**

***Keywords*—circuit design, on-demand video education, online class, video lecture**

I. Introduction

As the recent pandemic of COVID-19 reshapes the world, industrial electronics education is confronting fierce pressure to shift educational activities to digitized online classes [1][2]. Propelled by this pressure, a number of university lecture courses are recently provided via the internet [3]-[5]. This digital transformation of education was strongly supported by the recent progress of information technology and the rapid spread of the network infrastructure. Nonetheless, despite the wide variety of sophisticated web teaching systems like Google Classroom, Microsoft Teams, Moodle, etc., online classes may offer worse educational quality compared with the conventional on-site classes [6]-[8], which needs to be solved by the development of the teaching method more suitable for the online classes.

The basic styles of the online lecture classes can be classified into two forms as illustrated in Fig. 1: (a) The real-time web meeting class [9][10], and (b) The on-demand video streaming class [11]-[13]. The former form is the simple method of digital transformation, as the on-site lectures are shifted into the web meeting service without the fundamental change of the basic teaching material and teaching format. Furthermore, the recent sophisticated web meeting services enable real-time communication with the students, which gives the key for the teacher to provoke the students' interest and motivation. However, this style requires the network infrastructure to tolerate the enormous data transition with all the students with sufficient telecommunication speed, which may cause difficulty if a massive number of online lecture courses are supplied in this form at the same time as in the university. Furthermore, this lecture style requires all the students to attend the online class simultaneously. Therefore, this style may be difficult if the students belong to various affiliations and/or the students have different professions as in the continuing education for professional engineers.

These drawbacks of the real-time web meeting class can be mitigated by adopting the on-demand video streaming class. This class allows a more flexible schedule for the students to watch the video, and therefore this class can add less burden on the network infrastructure. Furthermore, this flexibility in the schedule can accept students with a greater variety of backgrounds as affiliations and professions.

However, the major drawback of this style is the lack of real-time communication with the students. Certainly, the teacher can answer the students' questions quickly via email or online chat services. Nonetheless, these non-real-time tools are less effective than the real-time communication between the teacher and the students for orienting the students' attention and provoking their motivation in the topic of the lecture. Consequently, the teacher should seek another

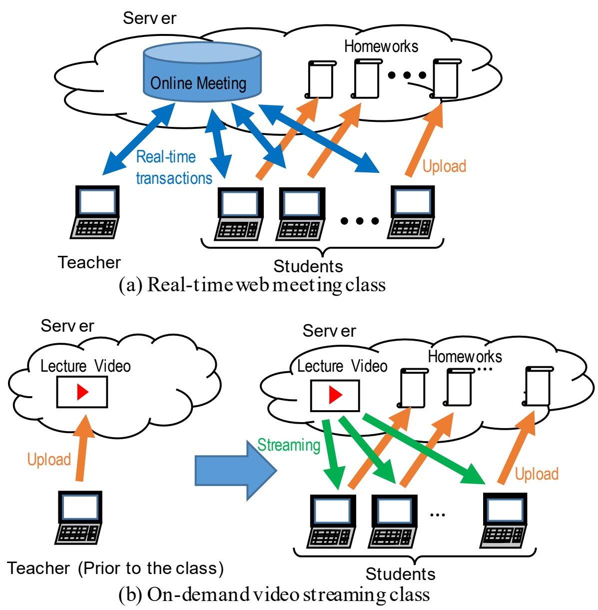

Fig. 1. Basic styles of the online lecture classes.

methodology to provoke the students' motivation without real-time communication, which has been scarcely established for the on-demand video streaming class.

Regarding industrial electronics education, the on-demand video streaming class is particularly attractive because industrial electronics education is needed by a wide variety of students ranging from university students to professional engineers. Propelled by this benefit, many on-demand video streaming lecture courses are being provided for teaching industrial electronics. At the same time, however, the aforementioned drawback of the on-demand video streaming class appears particularly critical because the practical aspect of the technology occupies an essential part of the education even though many students can be before engaged in the industry and not strongly motivated by the technology.

Conventionally, a number of insights have been pointed out in literature to provoke the students' motivation based on the experiences of various on-demand video streaming classes. For example, [14] encouraged the teacher to provide information that can only be obtained from the videos. [15] proposes to adopt the thematic instructional strategy as the interactive on-demand video streaming system, which may require a sophisticated learning system. [16] advises that the interactive feature, such as bookmarking, should be implemented in the system. These insights were effective to improve the education quality. Nonetheless, the application of these insights needs a special on-demand video streaming system or special information for education, which may be hardly available in many educational scenes. In this sense, the educational method should also be investigated for better on-demand video streaming classes, which are expected to be more universally applicable.

The purpose of this paper is to propose a teaching method for the on-demand video streaming classes designed to educate the practical electric power circuit design. This method aims at provoking the motivation of the students, who have the basic knowledge of the electric circuit but scarcely have experience in circuit design. For motivating the students, this teaching method presents the experiment showing the performance of an actual electric power circuit, along with the explanation of the electric power circuit design, in each class, i.e. the streaming video. Then, the teacher gives the homework that requests the students to propose the best design of this experimental circuit and explain the reason. By inviting the students to propose an optimal solution, the students can consider the practical performance issues and the various design considerations of the experimental electric circuit. This can encourage the students to imagine the actual possible problems encountered by the circuit design engineers and think of various possible approaches to solving this problem, which is expected to provoke students' motivation to the technology.

The remainder of this paper discusses this proposed teaching method by reporting an actual on-demand video streaming lecture course designed according to this teaching method, which was held for university graduate course students in 2021. Section II explains the proposed teaching method. Section III reports this lecture course and shares the experiences obtained through the course. Section IV presents the questionnaire survey results answered by the students. Finally, section V gives the conclusions.

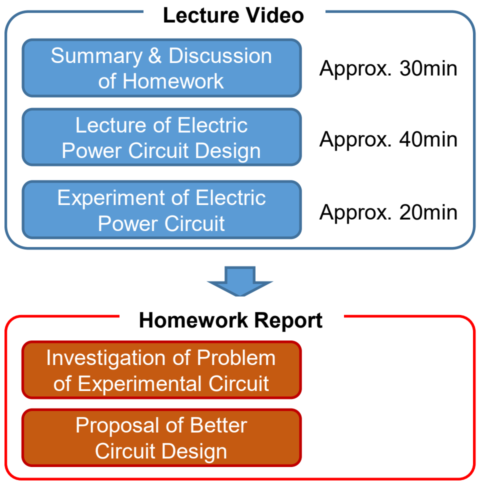

Fig. 2. Construction of each class according to proposed teaching method.

II. TEACHING METHOD

Similar to many other fields of industrial electronics, the electric power circuit design needs the integration of various engineering knowledge covering circuit theory, electromagnetism, transmission line theory, control theory, heat transfer engineering, etc. This feature of the electric power circuit design does not accept the teaching method based on merely transferring the knowledge but rather needs the students' active usage of their engineering knowledge. For encouraging the students, this method firstly explains the basic engineering knowledge and presents an experiment to show the operation and performance of an actual electric power circuit; then the students are invited to propose the possible optimal design regarding the experimental power circuit as the homework.

In the on-site class or the real-time web meeting class, this process of showing the experiment and discussing the optimal design can be conducted within the class. However, the on-demand video streaming class does not have an opportunity to have real-time communication between the teacher and the students during video watching. Therefore, the students' output, i.e. their proposal, must be submitted as homework. Consequently, the teacher assigns the proposal of optimal design as homework, and the students' reports of the proposal are summarized and reviewed by the teacher in the video of the next class.

Consequently, according to the proposed teaching method, the video of each class comprises the following three parts, as shown in Fig. 2:

1. Summary and review of the students' homework, i.e. proposal of optimal design regarding the experimental circuit of the previous class,
2. Lecture on the electric power circuit design regarding the topic of this class,
3. Experiment showing the operation, performance, and problems of the electric power circuit of the topic of this class.

The 2nd part, i.e. the lecture part, gives the students the basic knowledge of the electric power circuit of this class. The teacher explains the circuit topology and the basic circuit operation. Then, based on this knowledge, the teacher further explains the basic design approach for this circuit. The teacher should also remind the students about the difference between the basic design approach and the actual optimal design. The circuit design should consider not only the circuit operation but also various factors and limitations imposed by the application as well as the limitation of the circuit elements available in the market. In this sense, the optimal design is different depending on the requirement specifications and therefore the straightforward following of the basic design approach will not lead to the optimal design. By explaining the difference between the basic design approach and the actual design, the teacher should orient the students' attention toward these factors and limitations in the actual circuit design, which is fundamentally important for working on the homework.

The experiment part, i.e. the 3rd part, shows the circuit operation and performance of an actual circuit to confirm the knowledge explained in the 2nd part. At the same time, this part presents sufficient information for the homework. For this purpose, the experiment part also presents the circuit schematics and the detailed specifications of the circuit elements in the experimental circuit along with the experimental results. Nonetheless, the teacher can also hide some critical design information, regarding what the teacher wants to have the students think of as the optimal design.

The electric power circuit design includes a wide variation of the design points. For example, the teacher can have the students propose the optimal circuit topology or the optimal value of the circuit elements, such as resistance, capacitance, and inductance. Besides, the teacher can have the students propose the optimal choice of the circuit elements from commercially available actual circuit elements or the cost-competitive heat dissipation method.

The electric power circuit design must consider various aspects including the operation, performance, size, power consumption, cost, etc. Hence, there can be more than one option in the possible optimal design. The teacher should request the students not only to specify their optimal design but also to discuss the reason for their proposal in the report. This reason will be shared among the students by summarizing, reviewing, and rating by the teacher in the first part of the next class's video.

III. Lecture Course on Electric Power Circuit Design

A. *Overview of Lecture Course*

This section reports on the lecture course on electric power circuit design at Okayama University, Japan in 2021. This lecture course is originally designed according to the proposed education method because this course is firstly started in 2021.

In total, 19 students joined this course. Among them, 14 students are in the first grade of the postgraduate course and 5 students are in the fourth grade of the undergraduate course. These students have already learned the basic knowledge of electronics as the linear circuit theory, electromagnetism, and electric circuit.

This course was provided as an on-demand video streaming course party due to the pandemic of COVID-19 in Japan but also due to the wide background of the students. All the students, including the 4th grade of the undergraduate course, belong to various research laboratories at the university. Therefore, each student participating in this lecture course must perform the research activities of his own laboratory, which sometimes causes obstacles to scheduling

Class	Topic of Lecture	Design Field
#1	Guidance to Circuit Design	N/A
#2	Rectification Circuit	Diode & Capacitor Design and Choice
#3	Suppression of Inrush Current	Driving Circuit Design of Relay
#4	Linear Regulator	Choice of Linear Regulator
#5	Heat Dissipation	Estimation of Max. Output Power
#6	Integrated circuit inside linear regulator	Basic Design of Analog Power Circuit
#7	Overcurrent & Overheat Protection of ICs	Protection Circuit for Analog ICs
#8	Charge Pump	Design and Choice of Charge Pump Circuit Elements

Fig. 3. Topics and design fields targetted in each class.

the fixed time for the lecture. Consequently, the lecture course should offer high flexibility in the time for these students.

To cope with this request, this course was provided by online tools. The lecture video of each class was provided as pre-recorded video streaming via Microsoft Stream. The students handed in their reports using Moodle.

Figure 3 lists the topic of each class. This course in 2021 has 8 classes in total. As the first class is the guidance session that gives an overview of this technical field, this course gives lectures on 7 fundamental types of practical circuit design. Certainly, these 7 lectures can cover only a small part of the technical field of electrics power circuit design. However, these 7 lectures aim at teaching the practical design considerations common to various electric power circuit designs.

The video of each class had a duration of 90 minutes approximately. Part 1, i.e. the summary and review of the students' proposal as well as presentation of the teacher's proposal, took approximately 30 minutes. Part 2, i.e. the lecture on the electric power circuit design, took approximately 40 minutes. Finally, part 3, i.e. the experiment, took 20 minutes. After the issue of the video, the students were requested to hand in the proposal within a week.

B. *Example of Video and Homework*

This subsection presents the 2nd class of this lecture course as a practical example of the proposed education method. The topic of the 2nd class is the rectification circuit. As this is the first class after the guidance, an elementary technique was chosen as the topic of this class.

This subsection firstly explains the lecture part, which corresponds to the 2nd part of Fig. 2. Subsequently, the experiment part, i.e. the 3rd part of Fig. 2, is explained. Then, the homework for this class is presented. Finally, the review of homework is presented, which was broadcasted in the 1st part of the lecture video of the 3rd class.

1) *Lecture Part*

Because the first class gives the guidance of the lecture course and did not assign the homework, the video of the 2nd class started from the lecture part. This part focus on a very typical rectifier circuit known as the full-bridge rectification circuit with the transformer as shown in Fig. 4. The lecture part starts with a review of the theoretical operation analysis

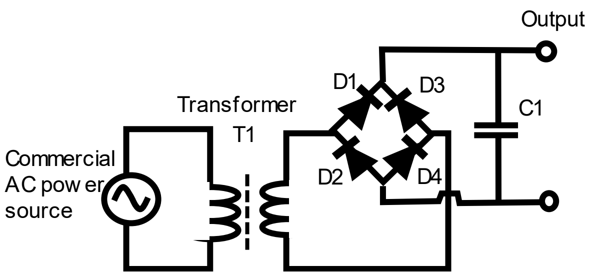

Fig. 4. Full-bridge rectification circuit with the transformer.

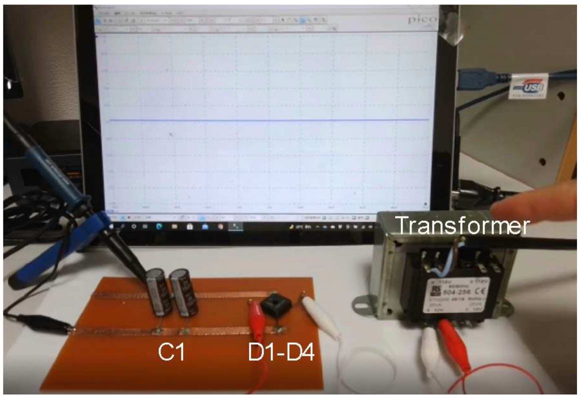

Fig. 5. Photograph of experimental prototype.

of this rectification circuit. This review is based on the basic electric circuit theory taught in the university's undergraduate course education, which neglects the nonlinear characteristic of the diode D1-D4, the parasitic elements of the transformer T1, and the output smoothing capacitor C1. However, these neglected parameters actually have a non-negligible effect on the output voltage of an actual rectification circuit, which will be shown in the experiment part of the video.

After the theoretical review of the circuit operation, the video explains the basic design method of the full-bridge rectification circuit based on the electric circuit theory. This design method covers the essential design consideration for implementing the basic operation of the rectification circuit without damaging the circuit elements. Specifically, the turn ratio of the transformer is designed according to the requirement specification of the input and output voltage; the output capacitance and the necessary withstand current of the output capacitor are designed according to the requirement specification of the output voltage ripple and the output current; the necessary withstand voltage and current of the diode are designed according to the requirement specification of the output voltage and current, and so on. This design method is sufficient for conceptual design. However, this method does not necessarily lead to the optimal design in practical circuit design, because it does not consider the aforementioned neglected parameters.

2) Experiment Part

Subsequently, the video enters the experiment part, which corresponds to the 3rd part of Fig. 2. This part shows the operating waveforms and the performance evaluation results of the prototype designed according to the aforementioned designed method. This part firstly explains the circuit diagram of the prototype as well as the circuit elements chosen for this prototype. Secondly, this part explains how this prototype was designed to meet the specifications given for the prototype. Thirdly, the operating waveforms were shown to confirm how well the operation is consistent with the theory. Finally, the performance evaluation results, e.g. the output voltage dependence on the output current, were presented to focus on the discrepancy between the theoretically expected performance and the real performance. As in many practical electric power circuits, an actual circuit exhibits worse performance than expected from the theory. As for the 2nd class, the prototype of the full-bridge rectification circuit, shown in Fig. 5, exhibited a smaller output voltage than expected from the theory. This video tries to show various waveforms that can give hints of the reason for the output voltage decrease.

3) Homework

The teacher assigns the proposal to improve the performance as the homework. The homework of the 2nd class requested to propose a better design to reduce the output voltage decrease compared to the theoretical value. The proposal should be as concrete as possible. For example, if the students propose to replace a circuit element with a better one, they are requested to specify the product ID of this circuit element. At the same time, the proposal should also explain the reason for this replacement in as detail as possible.

Commonly as in the practical circuit design, some natural limitations are imposed on the proposal. In the homework of all the classes, the proposed design is requested to be able to be made of commercially available circuit elements: All the circuit elements can be purchased by the common online shopping site such as RS Components, Digikey, Mouser, etc. Besides, the homework of the 2nd class requested not to replace the transformer with other transformers, although the winding connection can be changed. When the teacher assigns the homework, the teacher provides the datasheet of all the circuit elements utilized in the prototype to supply sufficient information to the students for analyzing the problems of the prototype.

4) Review of Homework

The submission deadline of the homework was set at the day before the next class. After collecting and checking the submissions, the teacher records the video summarizing and reviewing the students' proposals, which will be the 1st part of the lecture video for the 3rd class. There is more than a single solution to improve performance. Therefore, the students' proposals commonly have a great variety. The teacher categorizes these proposals into some distinctive approaches and comments on how effective these approaches are. It is also important for the teacher to comment on the possibility to combine some approaches for the best performance.

As for the 2nd class, the proposals from the students mainly focused on the replacement of the junction type diode with the Schottky-barrier diode to reduce the forward voltage drop. However, there is a proposal that commented on a more

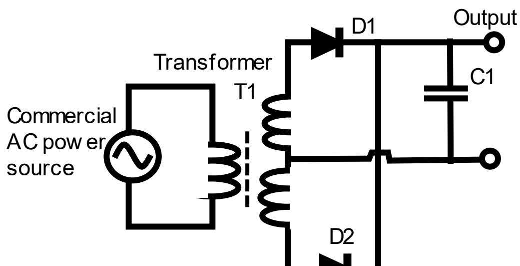

Fig. 6. Proposal of better secondary winding connection.

TABLE I. SURVEY RESULT OF OVERALL EDUCATION EFFECT

	Whole Lecture	Experiment	Homework
Strong Agree	12	8	8
Somewhat Agree	0	3	4
Neutral	0	1	0
Somewhat Disagree	0	0	0
Strong Disagree	0	0	0

effective method to revise the secondary winding connection as shown in Fig. 6. The teacher introduced both approaches and commented on the estimation of these effects on the output voltage as well as the effect when these two approaches are combined.

IV. CLASS EVALUATION SURVEY RESULTS

At the end of the on-demand video lecture course on electric power circuit design in 2021, the student' survey was conducted to evaluate the effectiveness of the proposed education method. This survey was answered by 12 students out of 19 participants; 3 students of these students are undergraduate students. Similar to many students' surveys, this survey asked many ordinary questions that evaluate the education quality of this lecture course. Additionally, this survey includes some questions regarding the experimental part and the homework, which are characteristic of the proposed education method. The students are informed that their answers have absolutely no effect on their grades.

To evaluate the overall quality of the lecture course, this survey asked the students to give scores ranging 1–5 on the educational effectiveness of the whole course as well as that of the experiment part and the homework. Scores 5, 4, 3, 2, and 1 represent that the student feels "strong agreement", "somewhat agreement", "Neutral," "somewhat disagreement," and "strong disagreement" with the educational effect, respectively. Table I shows the results. As can be seen in the figure, all the students gave a positive assessment of the educational quality of the whole course, the experimental part, and the homework. Actually, the majority of the students scored 5, i.e. "strong agreement", on these three questions.

Then, this survey asked the students how effective the experimental part of the lecture videos was. For this purpose, the students are given the following 5 answer choices (the students were allowed to mark multiple choices):

A) The operating waveforms shown in the experiment helped the understanding of the circuit operation;

B) The experiment stimulated the interest in the electric power circuit;

C) The actual power circuit shown in the experiment helped the understanding of the power circuit;

D) The circuit performance evaluation shown in the experiment helped the discrepancy between the theory and the practical circuit.

E) The actual circuit was too complicated to clearly understand the circuit operation.

Figure 7 shows the survey results on the experimental part. This figure shows the percentage of the students that marked

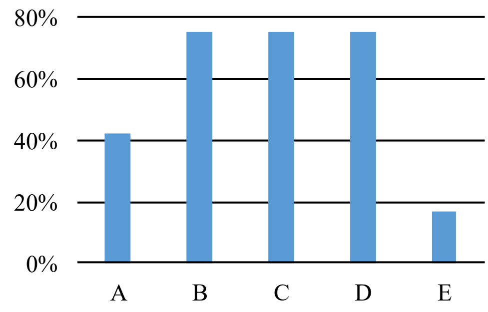

Fig. 7. Percentage of students who marked answer choises regarding experimental part of lecture video.

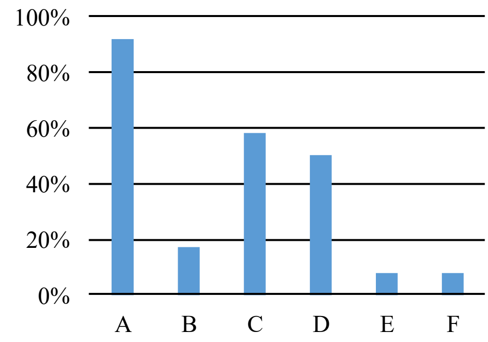

Fig. 8. Percentage of students who marked answer choises regarding homework.

this choice out of the 12 students. The results show that 75% of the students marked 'B'-'D' and only 17% of the students marked 'E', which supports the effectiveness of the experimental part for improving education quality. Certainly, the students marked 'A' were fewer than half of the 12 students. In this video, the circuit operating waveforms were shown by filming the screen of the oscilloscope with the video. Therefore, the screen of the oscilloscope may have not been shot clearly due to the limitation of the video resolution, which should be improved in the future lecture.

Next, this survey asked the students how effective the homework was. For this purpose, the students are given the following 6 answer choices (the students were allowed to mark multiple choices):

A) The homework was a good opportunity to review the lecture;

B) The homework gives the motivation to concentrate on the video lecture;

C) The homework was a good opportunity to exercise the application of the technology;

D) The difficulty level of the homework was moderate;

E) The review of the homework is sufficient to understand only in the lecture video;

F) The homework took too long time.

Figure 8 shows the survey results on the homework. This figure also shows the percentage of the students. The result showed a high percentage in 'A' and comparatively good percentages in 'C', which supports the effectiveness of the homework. Furthermore, only 8% of the students marked 'F' and a comparatively good percentage of the students marked 'D', which supports that the homework was of suitable difficulty level for the students. However, only 17% and 8% of the students marked 'B' and 'E', which implies the review of the homework is not sufficient and does not effectively contribute to the students' motivation. The reason is not clear in this survey. However, the lack of discussion between the teacher and the students as well as discussion among students, which is the prominent drawback of the on-demand video streaming lecture course, may still have deteriorated the education quality. Therefore, the method of reviewing the homework should be improved in future lecture courses.

Consequently, the proposed education method can be expected to have a positive educational effect on the on-demand video streaming course on electric power circuit design, although further improvement will be needed in the clear presentation of the circuit operation and reviewing the students' homework.

V. Conclusions

The on-demand video streaming lecture courses are effective for accepting students from various backgrounds like occupations and affiliations. However, the lack of real-time communication with the students makes it difficult to orient the students' attention and provoke their motivation in the topic of the lecture. To overcome this difficulty in the education of the electric power circuit design, this paper proposed a novel education approach, which engages the students in considering the practical performance issues and the various design considerations of the experimental electric circuit. This method aimed at encouraging the students to imagine the actual possible problems encountered by the circuit design engineers and think of various possible approaches to solving these problems, thus motivating the students in the electric power circuit design.

The students' survey of the on-demand video lecture course according to the proposed method was performed to evaluate the proposed method. As a result, the overall education quality is positively evaluated by the students. Particularly, the experiment was evaluated to be useful for promoting the understanding of the circuit design and stimulating the interest in the electric power circuit. However, clear filming of the instrument's output like an oscilloscope should be sought in the future lecture course. The homework was also evaluated positively for helping the students to review the lecture. However, the homework was pointed out to be insufficient to promote the students' motivation and understanding, which should also be addressed in the future lecture.

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