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*Research Article*

# Effective Teaching Design Based on the Combination of BOPPPS Model and Tina Virtual Simulation Software

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Good teaching effect comes from effective teaching design. In this article, we combined the advanced teaching concept BOPPPS model with Tina virtual simulation software to develop the teaching design. BOPPPS model is an effective and efficient teaching model. It includes six parts such as bridge-in, objective, preassessment, participatory learning, postassessment, and summary. In this article, bridge-in is introduced by practical examples of triode amplifier circuits. Objective includes knowledge objective, ability objective, and value objective. Preassessment is realized by simulating the triode output characteristic. Participatory learning is presented by simulating three kinds of basic amplifier circuits and analyzing simulation results. Besides that, flipping classroom is designed to stimulate students' learning enthusiasm and innovation ability. Postassessment is completed by asking some questions. Summary is completed by students and supplemented by teachers. In this process, different simulation waveforms are obtained by using the Tina virtual software to simulate the various circuits layer by layer. Practice has shown that the proposed method not only improves students' ability of analyzing and designing practical circuits, but also stimulates students' learning enthusiasm. Teaching design ideas become clearer, and the teaching quality is improved.

## 1. Introduction

Effective teaching design plays a vital role in improving teaching quality. With the rapid development of information technology and computer technology, many advanced teaching concepts were used in teaching design. Especially, with the wide application of online resources, online and offline mixed teaching mode is widely used in teaching. Teachers are concerned about how to integrate information technology with the advanced teaching concepts to better promote the teaching quality. Virtual simulation technology makes full use of various information technologies and plays an important role in modern teaching modes. Tina, as a computer-aided virtual simulation software, contains about 20000 discrete or integrated circuit components. Usually, it can design and simulate various complex analog circuits and digital circuits. Its main functions include direct-current analysis, transient analysis, sinusoidal steady-state analysis, temperature scanning, fourier analysis, and parameter scanning. In the actual application, the software plays high-efficiency and high-precision role in the development of electronic products. So, it is very suitable for simulating various analog and digital circuits. Tina interface is shown in Figure 1. In the interface, it is convenient to draw graphics, and students can observe the simulation results intuitively, so that the corresponding conclusions can be obtained based on the simulation results. With the help of Tina virtual simulation software, students can combine theory and practice more closely, thus promoting the teaching quality.

Recently, many scholars have made some gratifying achievements by using the Tina software. Wu et al. [1] introduced a noise suppression network with automatic adjustable parameters by Tina software. Derkaoui et al. [2] used the Tina software to simulate the forward converter. Zhang and Huang [3] built a heart sound signal and proved that

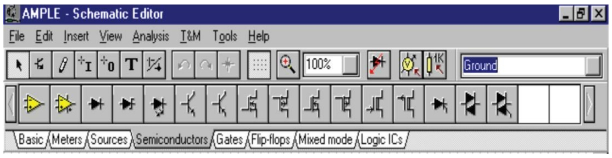



Figure 1: Tina virtual simulation software interface.

good teaching effect can be achieved through virtual simulation analysis. Meng et al. [4] applied Tina software to simulate heat conduction problems, the results showed the satisfactory results. The above mentioned references have achieved certain results using the Tina software. However, most of them do not discuss the characteristics of Tina software. They do not achieve results by improving the circuits layer by layer. In fact, Tina software has a powerful simulation function [5], while it has more obvious advantages in simulating analog electronic circuits and digital electronic circuits. So, it needs to formulate effective teaching design based on the characteristics of the software and course. In this article, we used the Tina software to gradually improve the amplifier circuit in analog electronics technology course. The proposed method can better improve the teaching design quality.

On the other hand, in order to further develop teaching quality, effective teaching design is essential. BOPPPS model is considered as an "effective," "efficient," and "beneficial" teaching model. It is created by the Canadian teacher skills training workshop [6]. The model includes six parts: bridge-in, objective, preassessment, participatory learning, post-assessment, and summary. BOPPPS comes from the acronyms of English words in each part. Its meaning of each part is shown in Figure 2.

BOPPPS model emphasizes the students' participation and feedback. It can provide good teaching results and improve the satisfaction of learners [7]. Furthermore, it is very beneficial to promote students' deep learning and apply the related skills to solve the practical problems. Besides that, it is useful to improve the teaching quality by actively exploring the innovation and reform. It also provides teachers to guide the teaching design and makes teaching design more reasonable and scientific.

We developed the teaching design based on BOPPPS model and Tina virtual simulation software. Its structure is as follows: Section 2 presents the triode amplifier circuit teaching design based on BOPPPS model and Tina simulation software. In this process, the circuits are simulated using a step-by-step questioning method. In the meantime, flipped classroom is used to further promote teaching reform. Section 3 presents the teaching effects. In Section 4, the discussion and conclusion are presented in detail.

## 2. Effective Teaching Design Based on BOPPPS Model and Tina Virtual Simulation Software

Recently, virtual simulation technology was introduced to assist theoretical teaching and experiments. Tina software can intuitively and vividly show the simulation results to students. The simulation results are helpful to stimulate students' enthusiasm and subjective initiative. In order to better carry out teaching design according to the six parts of the BOPPPS model, we used BOPPPS model as the foundation and used Tina virtual simulation software as the auxiliary tool.

*2.1. Bridge-In.* Interestingly bridge-in will attract students' attention and improve their learning interest. Students can know the theme and importance of learning content according to the bridge-in. Bridge-in can be performed by pictures, videos, or real objects. The triode amplifier circuit is the basic unit of a complex circuit. At present, many electronic systems need amplifier circuits, such as mobile phones, radios, loudspeakers, and stethoscopes. These devices are closely connected with students and can inspire their learning interest more.

*2.2. Objective.* Teaching objective enables students to understand the requirements that they need to achieve. It is the interaction between teaching and learning. Teaching design is always guided by teaching objective. Teaching objective includes knowledge objective, ability objective, and value objective. Teacher should clearly point out the knowledge objective. Ability objective is reflected by using Tina software to simulate and design circuits. Value objective refers to the pursuit and aspiration of students, which is obtained by group discussions, flipped classroom, and electronic production display. Table 1 shows the teaching objective of the triode amplifier circuit.

*2.3. Preassessment.* Preassessment mainly assesses students' prior knowledge and helps the teacher to adjust the teaching strategies based on the preassessment results. In this process, it is necessary to master the real cognition of students.

To learn the triode amplifier circuit, student must master the working areas of triode. Working areas include three areas such as amplification area, cut-off area, and saturation area. The output characteristic of a triode amplifier circuit and its simulation result based on Tina virtual software is shown in Figure 3. Tina software has the ability to perform DC analysis, AC analysis, and transient analysis [8]. So, it is useful to facilitate students to better understand the relevant circuit.

Special note: the horizontal coordinate of simulation diagrams from Figures 3 to 8 is time (unit in S), and the vertical coordinate is voltage or current (unit in V or A). Besides that, due to Tina software limitations, the u and U, as well as I and i, involved in the figures of this article are not distinguished.

*2.4. Participatory Learning.* As the core of BOPPPS model, participatory learning takes students as the centre, encourages students to actively participate, exchange information and feedback between teachers and students, so that students can deeply apply knowledge to practice. In this process, the teacher may design multiple interactive strategies such as group discussions or individual reports. It is

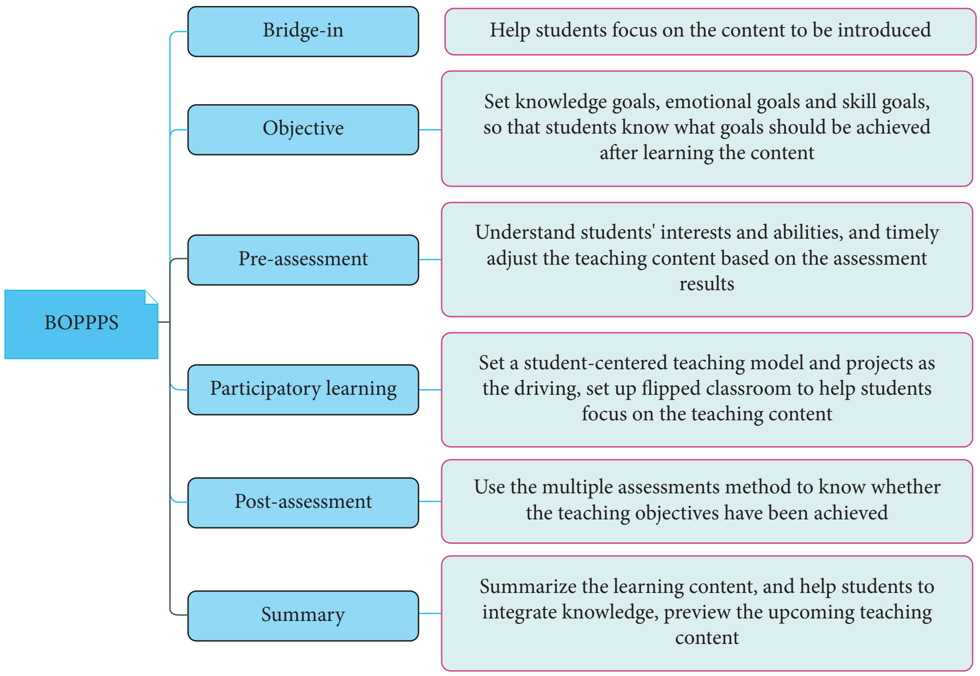
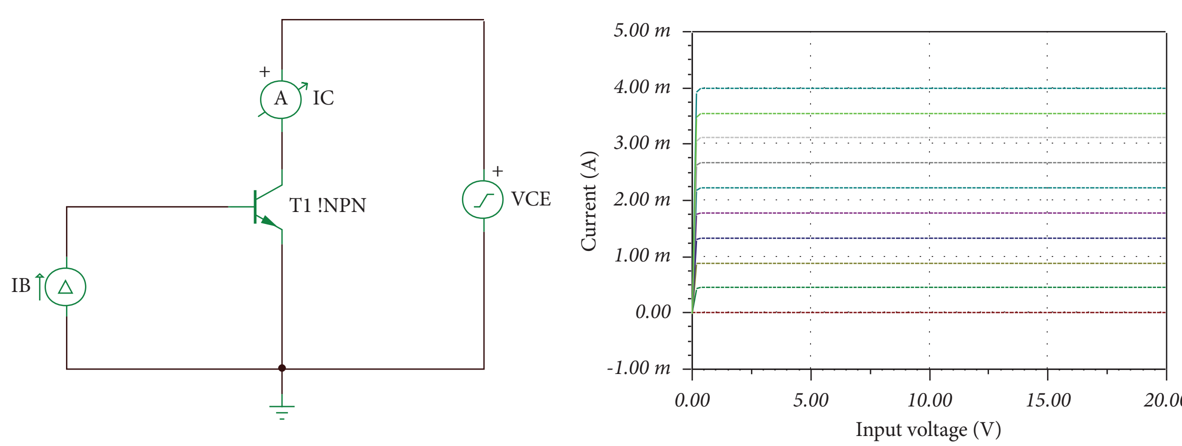



Figure 2: BOPPPS model.

Table 1: Teaching objective of triode amplifier circuit.

| | |
|---|---|
| Knowledge objective | Master simulation waveform characteristics of triode amplifier circuits and draw the relevant conclusions |
| Ability objective | Use the Tina virtual simulation software to simulate several circuits, solve the practical problems of waveform distortion, and improve the theoretical analysis ability |
| Value objective | Cultivate the craftsman's spirit, professionalism, innovation awareness, group cooperation, and expression ability. |




(a)

(b)

Figure 3: Output characteristic of triode circuit and its simulation diagram. (a) Output characteristic of triode circuit. (b) Simulation diagram.

advantageous for promoting students to learn actively, think deeply, and innovate actively. In this article, we improved the students' participatory learning ability by gradually improving various amplifier circuits.

Figure 4(b) shows that the common emitter amplifier circuit can realize the in-phase current and antiphase voltage amplification. The results are basically the same as the theoretical analysis. The simulation diagram can clearly and

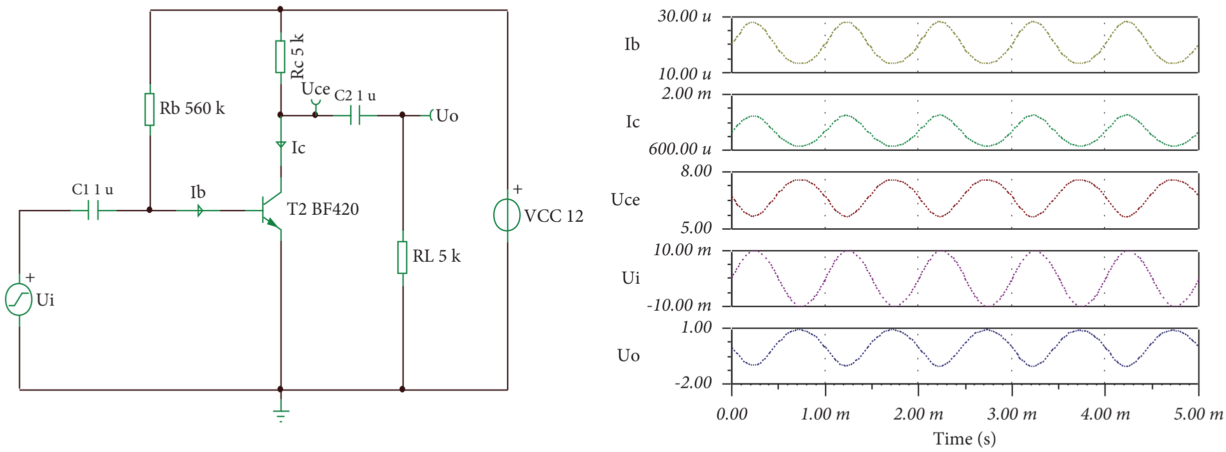



Figure 4: Common emitter amplifier circuit and simulation diagram. (a) Common emitter amplifier circuit. (b) Simulation diagram.

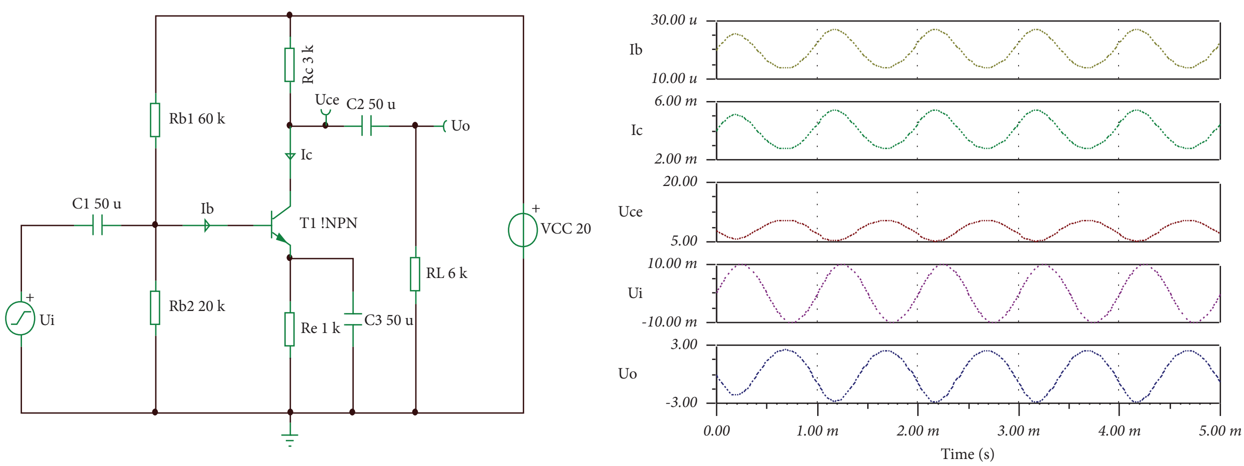



Figure 5: Division of the voltage bias circuit and simulation diagram. (a) Division of the voltage bias circuit. (b) Simulation diagram.

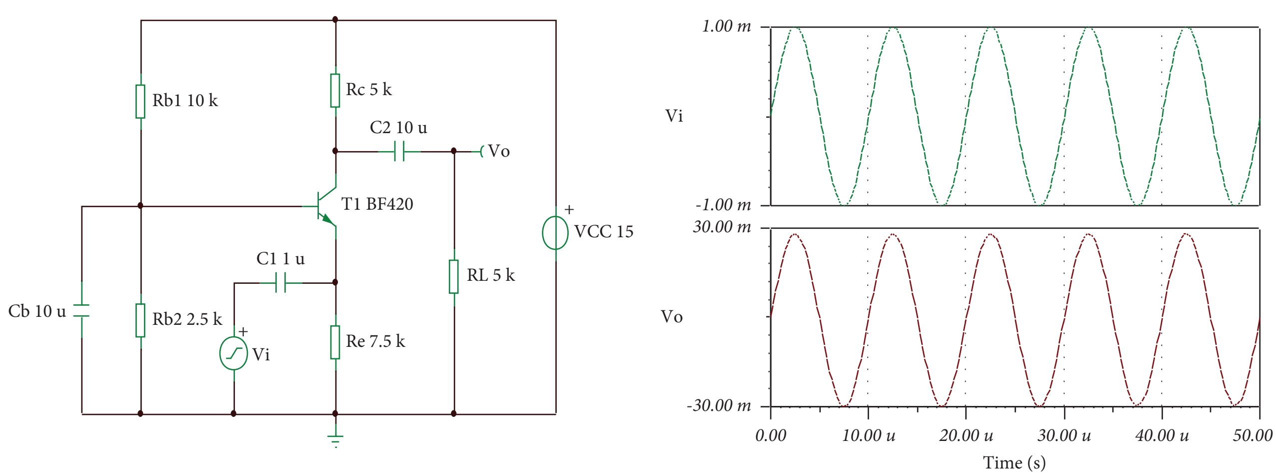



Figure 6: Common base amplifier circuit and simulation diagram. (a) Common base amplifier circuit. (b) Simulation diagram.

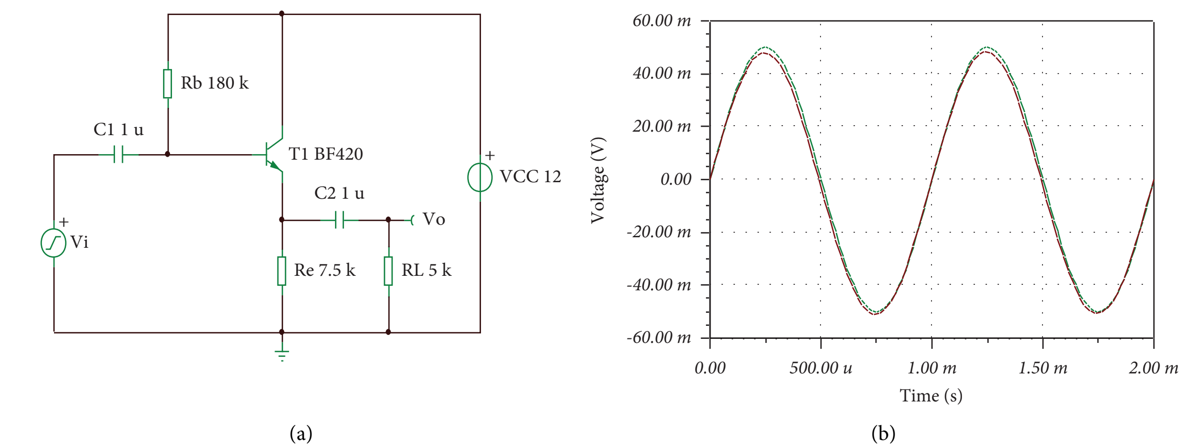



Figure 7: Common collector amplifier circuit and simulation diagram. (a) Common collector amplifier circuit. (b) Simulation diagram.

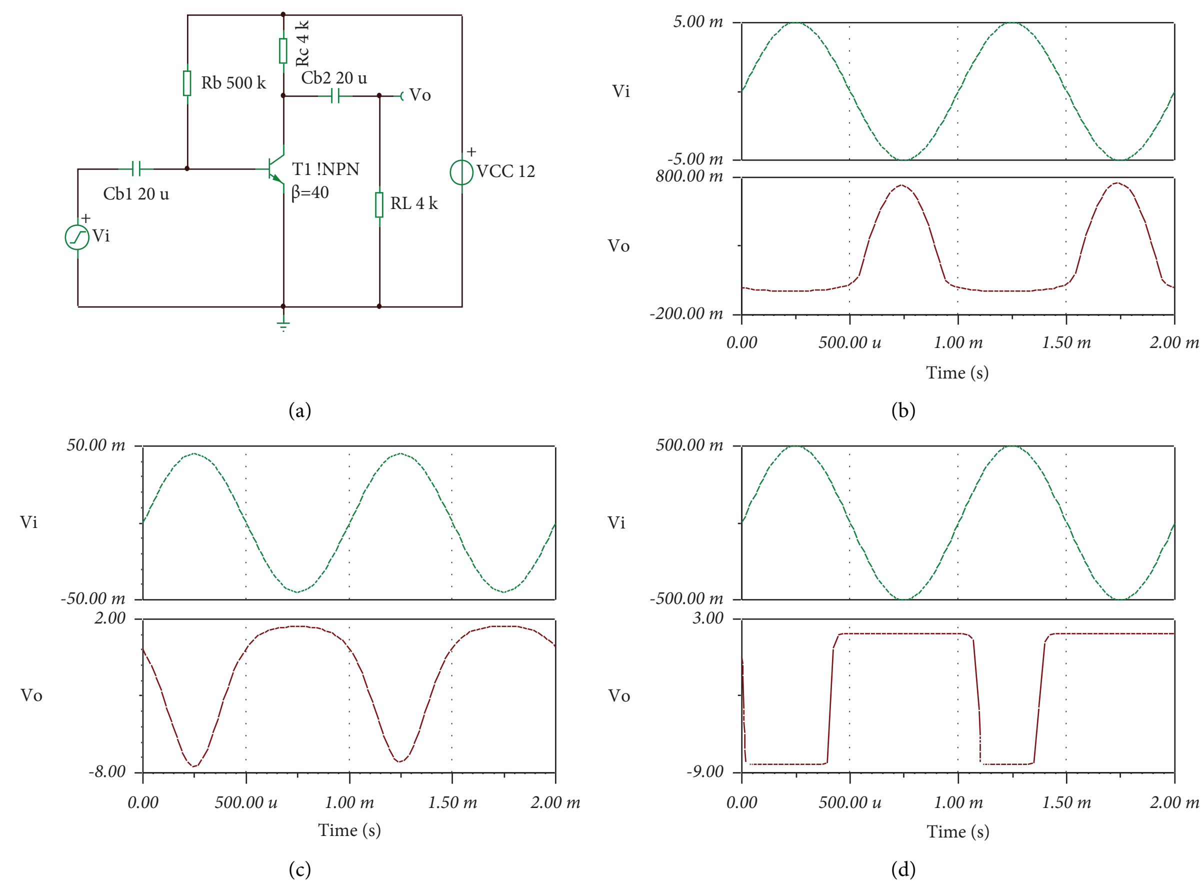



Figure 8: Distortion simulation of triode amplifier circuit. (a) Common emitter amplifier circuit. (b) Saturation distortion diagram. (c) Cut-off distortion diagram. (d) Large signal distortion diagram.

intuitively display each waveform and value. It is beneficial for students to master relevant knowledge.

The circuit of Figure 4(a) is simple and adjustable. However, external factors such as temperature change, triode aging, and voltage fluctuation will change the triode static working point. If this point is set inappropriately, it will make the circuit work improperly and cause waveform distortion. In order to reduce these unstable factors, the improved circuit is shown in Figure 5(a).

Figure 5(a) can stabilize the static working point. It realizes the in-phase current amplification antiphase voltage amplification. The simulation results are consistent with the theoretical analysis. In addition, the voltage amplification factor of Figure 5(a) should be lower than that of the circuit

Table 2: Features and applications of three amplifier circuits.

| Circuits | Common emitter amplifier circuit | Common base amplifier circuit | Common collector amplifier circuit |
|---|---|---|---|
| Features | It has the function of voltage and current amplification, and the input voltage phase is opposite to the output voltage. It may place in the middle stage of amplifier circuits | It has the feature of voltage amplification. However, it has no current amplification function. The output voltage has the same phase as the input voltage | It is called voltage follower. The voltage magnification factor is about 1. The input voltage and output voltage are in-phase. It has the function of current amplification |
| Indexes | $Av = -(\beta RL'/rbe)$ <br> $Ai = \beta$ | $Av = (\beta RL'/rbe)$ <br> $Ai = \alpha$ | $Av = (\beta RL')/(rbe + (1+\beta)RL')$ <br> $Ai = 1 + \beta$ |

in Figure 4(a) under the same parameters. Simulation conclusion is consistent with the theoretical analysis.

The common emitter amplifier circuit has the capability of voltage amplification and current amplification. Do all circuits have the characteristics? The common base amplifier circuit is introduced by setting this question.

The direct-current path and waveforms of Figure 6(a) is same as Figure 5(a) under the same parameters, so the waveforms of static working point are not shown in Figure 6(b). Figure 6(b) realizes the in-phase voltage amplification.

The common base amplifier circuit has the voltage amplification ability. Besides that, it has the characteristic of the current follower. Can the circuit achieve the voltage following capability? Subsequently, the common collector amplifier circuit is introduced by setting this question.

The static working point of Figure 7(a) is similar with Figure 4(a), so it does not simulate it in Figure 7(b). Figure 7(b) shows that the voltage gain is close to 1. It indicates that the circuit has a voltage following effect. So, it is called a voltage follower.

From Figures 4 to 7, we can obtain the conclusions shown in Table 2.

In the teaching process, it is very important to cultivate students' ability to solve practical problems. Next, the teaching design will be launched based on how to eliminate the circuit distortion.

Reasonable static working point can ensure the amplifier circuit to work well. However, this point may cause the nonlinear distortion due to the changes in the external environment. In Figure 8, it can observe the saturation distortion, cut-off distortion, and large signal distortion by setting different circuit parameters.

(a) If the signal amplitude of *vi* is set to 5 mv and Rb is set to 100 kΩ, the static working point is too high. It will cause the saturation distortion shown in Figure 8(b). Of course, the distortion can be eliminated by increasing the Rb value.

(b) If the signal amplitude of *vi* is set to 45 mv and Rb is set to 500 kΩ, the static working point is too low. It will cause the cut-off distortion shown in Figure 8(c). Of course, the distortion can be eliminated by reducing the Rb value.

(c) If the signal amplitude of *vi* is large, such as 500 mv, and other parameters remain unchanged, it will cause the large signal distortion shown in Figure 8(d). Of course, it may reduce the input signal amplitude to avoid the large signal distortion.

Furthermore, in order to further embody participatory learning, it may set the flipped classroom. Flipped classroom can improve the teaching quality according to the different characteristics of the students and teach students according to their aptitude in different levels [9]. Besides that, it brings students to develop their own self-learning strategies to adapt to the demands of the learning environment. Some researchers have achieved some results using flipped classrooms [10–14]. In many references, most students explain knowledge according to the teacher's requirements. The introduced course requires the combination of theory and practice, which reflects more aspects of students' innovative and practical abilities. So, the introduced flipped classroom mainly reflects the gradual improvement of students' circuitry, finds and solves practical problems, and gradually improves their comprehensive abilities such as practical innovation and group cooperation. The flipped classroom is very welcoming among students.

In this article, the basic requirements of the flipped classroom include the following points:

(a) Group and prepare Figures 4 to 8 circuits according to the independent group.

(b) Each group needs to make clear the following points:

① Master circuit characteristics, circuit working principles, circuit calculation methods, and circuit application areas.

② Use the Tina virtual simulation software adroitly, apply the software to build circuits, simulate circuits, analyze circuits, and design practical circuits.

③ Upload simulation results to the MOOC platform. Recently, online and offline mixed teaching mode become an important trend of teaching development under the background of "Internet +" [15]. Students not only can participate in the mutual evaluation on the MOOC platform, but also improve their own circuits by finding the advantages of other circuits.

④ If there is a circuit distortion phenomenon, how to eliminate the distortion. This method can cultivate students' ability to discover problems and solve practical problems.

(c) Additional points: simulate circuits that can stabilize the static working point. This process is conducive to hierarchical teaching based on students' learning situations. It can cultivate exploration, collaboration, and innovation abilities for students.

The flipped classroom is conducive to integrate theory with practice. It promotes students to participate in learning and improves students to solve the practical problem ability. Besides that, group discussion can encourage students to actively think, analyze, compare, judge, test, communicate, and cooperate. These aspects are conducive to cultivate students' deep understanding of team spirit and cooperation consciousness, and help them to achieve value objective.

*2.5. Postassessment.* Postassessment is beneficial for the teacher to master students' learning effects, and further improve the teaching design ability. Postassessment can be conducted by asking questions, questionnaire survey, homework, and test. In this article, postassessment allows students to observe the characteristics of distortion waveform and master some methods of elimination distortion. In addition, it may encourage students to finish the Table 3.

Table 3: Self-assessment form of the postassessment.

| Assess contents | Self-assessment results | | | | | |
|---|---|---|---|---|---|---|
| | Remember | Understand | Apply | Analyze | Evaluate | Create |
| Circuit structure | | | | | | |
| Simulate and analyze | | | | | | |
| Distortion analysis | | | | | | |
| Overall mastery | | | | | | |
| Harvest and reflection | | | | | | |
| Achieve objective? | | | | | | |
| Supplement | | | | | | |

Table 4: The distributions of the test scores.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Before reform | Score distribution | Score | <60 | 60–69 | 70–79 | 80–89 | 90–100 |
| | | Number | 14 | 25 | 33 | 43 | 11 |
| | | Proportion | 11.1% | 19.9% | 26.2% | 34.1% | 8.7% |
| After reform | Score distribution | Score | <60 | 60–69 | 70–79 | 80–89 | 90–100 |
| | | Number | 0 | 16 | 33 | 52 | 12 |
| | | Proportion | 0% | 14.2% | 29.2% | 46.0% | 10.6% |

*2.6. Summary.* Summary is to succinctly summarize the knowledge points, sort out, and review the teaching contents to further consolidate the teaching objective. In this article, teacher guides the students to summarize the circuit characteristics according to the circuit simulation results. In the meantime, the teacher may comment and replenish the relevant contents. In this stage, teacher may arrange preview tasks and provide some pertinent websites and materials. This method is useful for further cultivating students' ability to consult documents and materials.

BOPPPS teaching model can provide a complete teaching framework for teachers [16]. Tina virtual simulation software connects theory with practice more closely. The combination of BOPPPS model and Tina virtual simulation software benefits teachers and students more.

## 3. Effects

Combination of BOPPPS model with Tina simulation software can effectively improve the teaching quality. The effects can be considered from both the students and teachers. We tested the students in two classes. The number of students before the reform is 126, and the number of students after the reform is 113. The distributions of the test scores are shown in Table 4.

Table 4 shows that the scores after reform are generally higher than those before reform. For the before reform class, the number of students with a score of 90 to 100 is 11, its proportion is 8.7%, and the number of students with scores of less than 60 is 14, its proportion is 11.1%. While for the after reform class, the number of students with score of 90 to 100 is 12, its proportion is 10.6%, the proportion of high score students has increased by 1.9% than before reform class, and the percentage of students with scores ranging from 80 to 89 has increased by 11.9% compared to before reform class. Besides that, all test scores exceed 60. Moreover, students' electronic technology simulation capabilities and practical abilities have been effectively improved. They obtain better results when making electronic products. They actively participated in competitions and have achieved many outstanding results in the National Undergraduate Electronic Design Competition and National College Student Smart Car Competition. Teachers have also achieved excellent results. They participated in the teaching competition and won the first prize. They obtained many educational reform projects and published many teaching reform articles. Furthermore, the introduced course has been awarded many honorary titles such as provincial-level online first-class course, provincial-level online and offline mixed first-class course, and provincial-level top quality online open course. In summary, these achievements indicate that the proposed method is an effective teaching reform.

## 4. Discussion and Conclusion

As an effective teaching design model, BOPPPS provides a theoretical basis for teaching design. In practical applications, the six elements of BOPPPS model are not fixed. The sequences can be appropriately changed according to the characteristics of the curriculum contents and teachers. Besides that, it may comprehensively consider the teaching situation and students' learning level, and flexibly use the model to formulate an effective teaching design based on the course characteristics. In addition, according to the course characteristics, we introduced many practical circuits using the Tina virtual simulation software step-by-step. The introduced method makes teaching design ideas clearer and combines theory with practice more closely. However, since Tina software is suitable for designing small-scale circuits. As for complex circuits, it needs to further develop the Tina software characteristics to better meet the needs of practical circuit simulation and teaching design. In fact, according to the proposed method, students' enthusiasm for learning and practical ability can be effectively promoted by asking questions layer-by-layer. Moreover, flipped classroom encourages students to analyze and design circuits, cultivate and improve thinking ability and analyzing practical problems independently, mobilize their learning enthusiasm, and enhance their innovative consciousness. In a word, effective teaching design based on the combination BOPPPS model with Tina virtual simulation software will play an important practical significance for promoting the teaching reform and development.

Generally speaking, we find that small-class teaching may present better results than large-class teaching. In future, we will further explore how to better utilize the proposed method in large-class teaching to achieve better teaching results. Besides that, we will also expand the scope of our research and collect more feedback information to further provide a more scientific basis for teaching reform.

## Data Availability

The data used in this study are available from the author upon request.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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