

Research on the Application of Desktop Virtual Reality in Middle School Physics Experiment Teaching under the Cooperative Enquiry Mode

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ABSTRACT

As one of the important means of assisting experimental teaching, immersive virtual reality is limited by wearable devices in actual teaching environments, making it difficult to achieve large-scale application. In contrast, desktop virtual reality provides a feasible way to solve this problem with its low cost and convenience. However, there is currently a lack of in-depth research on how to effectively use desktop virtual reality to organize teaching activities. In view of this, this study carried out collaborative inquiry-based physics experimental teaching activities with the support of traditional real situations and desktop virtual reality. Through a comprehensive evaluation of the physics experimental abilities and related factors of students in the experimental group, the study found that: under the cooperative inquiry mode, physics experiment teaching organized based on desktop virtual reality technology can not only improve student performance, but also significantly alleviate some students' concerns about physics. fear of experiments, enhance their self-efficacy, and promote students' in-depth understanding of physical phenomena and laws. However, research has also found that overreliance on desktop virtual reality activities may undermine students' ability to design rigorous experiments based on real equipment.

Keywords: Middle school physics experiment, Desktop virtual reality, Assisted teaching, Collaborative inquiry teaching.

INTRODUCTION

In the field of contemporary education, the application of virtual reality (VR) provides an innovative solution to experimental scenarios where resources are scarce, high risk, or difficult to implement. By building an immersive and interactive experimental environment, VR technology not only provides students with an effective alternative learning method, but also significantly enhances students' subjectivity in the experimental process [1] and inspires them to be more active participatory attitude, thus greatly improving the effect of experimental teaching and the quality of learning experience [2]. According to the difference in immersion level, VR can be subdivided into two types: immersive virtual reality (IVR) and desktop virtual reality (DVR). In educational applications, although IVR has attracted much attention due to its excellent immersive experience, its high construction cost and complex operation requirements restrict its wide application in daily classroom teaching. In contrast, DVR has shown stronger universality advantages due to its economical construction cost and convenient operation, and thus has gained wider favor in teaching practice. It is worth noting that research shows that there is no significant difference between IVR and DVR in improving students' academic performance [3], and DVR can not only effectively improve students' academic performance [4] but also reduce certification load [5], highlighting high-potential students' educational value.

At the same time, it can be found that current research focuses on exploring the impact of DVR on students' learning outcomes, self-efficacy, etc., while empirical research on DVR-based teaching organization methods is relatively scarce. In view of this, this study takes "promoting students' all-round development" as the core concept. On the basis of in-depth study of existing educational technology theories, combined with the actual situation of physical experiment teaching, and drawing on advanced research results, it is committed to building a set of practical and DVR-based middle school physics experiment teaching plans. This study aims to explore how to cleverly integrate DVR technology into the physics teaching process under the framework of DVR technology, and provide strong guidance and support for students to carry out independent inquiry learning. Therefore, this study mainly solves three problems:

1. How to effectively organize collaborative inquiry-based physics experiment teaching based on DVR technology?
2. Does DVR technology have a substantial effect in improving students' understanding of physical knowledge and laws?
3. What are the advantages and limitations of organizing physics experiment teaching based on DVR technology?

LITERATURE REVIEW

Virtual Reality in Education

With the increasing popularity of computer-supported learning models in the field of education, virtual reality technology, which is based on computer technology, has shown a booming trend in educational application research. In terms of educational practice, virtual reality technology has been more widely used and explored in practical disciplines with strong experimental and operational characteristics due to its unique advantages. In the early research stage, scholars mainly focused on how to improve learners' experience and participation in informal learning situations. "Soft indicators". With the rapid development of technology, the cost of deploying virtual reality equipment has decreased, allowing it to emerge in formal education scenarios. N. Adamo-Villani's team pioneered the development of the first bilingual immersive virtual

learning environment for deaf and mute students. By integrating appealing graphics and realistic real-time 3D virtual scenes, it guides deaf and mute children to engage in the study of mathematics and science in a gamified way [6]. Louis innovatively applied virtual reality technology to the assessment of soft skills in the interdisciplinary field of STEM [7].

Advantages of DVR in Experimental Teaching

In the classification of virtual reality teaching systems, DVR and IVR have their own characteristics. DVR technology is based on the PC platform, mainly realizing virtual effects through visual presentation, and interacting with devices such as the mouse; while immersive virtual reality creates a complete virtual environment through all-round sensory experience. In comparison, DVR technology has been more widely used and studied in teaching practice due to its advantages of low cost and high convenience. Especially in the field of virtual experiments, the application of this technology shows a significant growth trend. Research shows that DVR-based physics experiments can provide learners with a controllable, detailed experimental environment and help deepen their understanding of physical laws. It is worth noting that this technology has a particularly significant promoting effect on middle school students. In addition, this technology can also enhance students' spatial perception and improve their sense of learning presence, thus promoting the cognitive process of physics learning [8]. In terms of theoretical teaching, DVR also plays an important role. Taking the "Electricity and Magnetism" unit of junior high school physics as an example, Wang used the association rule algorithm in data mining to analyze students' interactive behaviors and found that students with different experience levels, genders and academic levels showed significant differences in virtual interactive behaviors [9]. These findings provide a scientific basis for teaching students in accordance with their aptitude, so that desktop virtual technology not only serves experimental teaching, but also provides new ideas for the optimization of the overall teaching process.

RESEARCH METHODS

Experimental Subjects

This experiment selected the "experimental class-control class" model to organize research activities. In order to ensure the rigor of the research, two high school classes with very similar physics knowledge levels, grades and learning initiative were selected as research objects to carry out experimental activities. The control class will carry out physics experimental teaching in a traditional real situation. For the experimental class, the "High School Physics 3D Laboratory" software was selected to provide it with a DVR environment, and instant communication was provided to students through WeChat groups to provide timely guidance for the experimental activities of each group. Based on the needs of experimental teaching, it was decided to organize the experimental class in a group collaboration manner, that is, to divide the students participating in the experiment into several learning groups with a size of 4-5 people per group. In order to ensure the rigor of the research, in addition to the experimental situation and experimental equipment, the two teaching classes were provided with exactly the same learning conditions as much as possible during the experiment to reduce the influence of irrelevant variables on the research process.

Organization of Cooperative Inquiry-based Experimental Teaching

On the basis of summarizing the general rules of inquiry-based teaching activities, referring to the excellent examples of inquiry-based teaching in middle school physics [10], and comparing with my own actual teaching, the general steps of inquiry-based teaching in middle school

physics experiments under the DVR technology environment are summarized as shown in Figure 1:

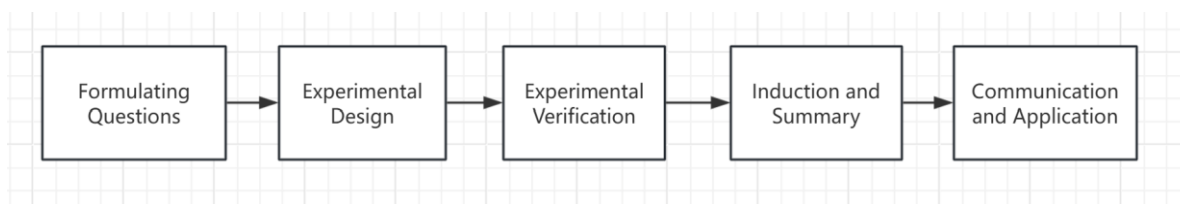


Figure 1: Steps of collaborative research teaching

The inquiry process includes:

1. Questioning: the stage of raising questions and forming hypotheses. The questions in the teacher's inquiry activities should be highlighted and inspiring to stimulate students' desire to explore and their intrinsic motivation to solve problems. The difficulty of the problem should be appropriate and fall within the students' zone of proximal development. It should be challenging and can be solved through students' efforts.
2. Experimental design: Under the premise of introducing the problem, students create scenarios and design experiments on the DVR technology platform in accordance with the problem. The design of the experiment and the construction of the experimental environment are implemented by the students themselves. This link can best reflect the students' creative thinking activities, and teachers do not need to intervene or ask.
3. Experimental verification: From hypothesis to experimental results, sometimes it is not possible to complete the experiment once, and sometimes even the experiment cannot produce results. Therefore, in the process of experimental verification, teachers should inspire students to think, find out the problem, and enable students to find solutions to the problem themselves.
4. Summarization: Students organize the conclusions drawn from the experiment, and then discuss in groups, exchange their experiences on the experiment, and evaluate the group members.
5. Communication and application: that is, applying what you have learned. The higher the level of generalization and systematization of existing knowledge and skills, the more likely you are to reveal the essential characteristics of knowledge and skills that you have not recognized before, incorporate them into your own cognitive structure, and then transform them into abilities.

Experimental Procedure

The teaching topic selected for this study is "Study of Uniformly Accelerated Rectilinear Motion". This topic is a very important experiment in the first volume of high school physics course. The purpose of this experiment is to verify the study of "the relationship between force, acceleration and distance " with the help of "discovery learning" so as to discover the internal law of uniformly accelerated rectilinear motion. In order to clarify the specific process arrangement of this experimental exploration, follow the norms of group collaborative learning [11], refer to the cooperative exploration teaching model, and take into account the factors of DVR technology, the model of this experimental activity is designed. Its basic process is shown in Figure 2.

“Cooperation -- inquiry”teaching model

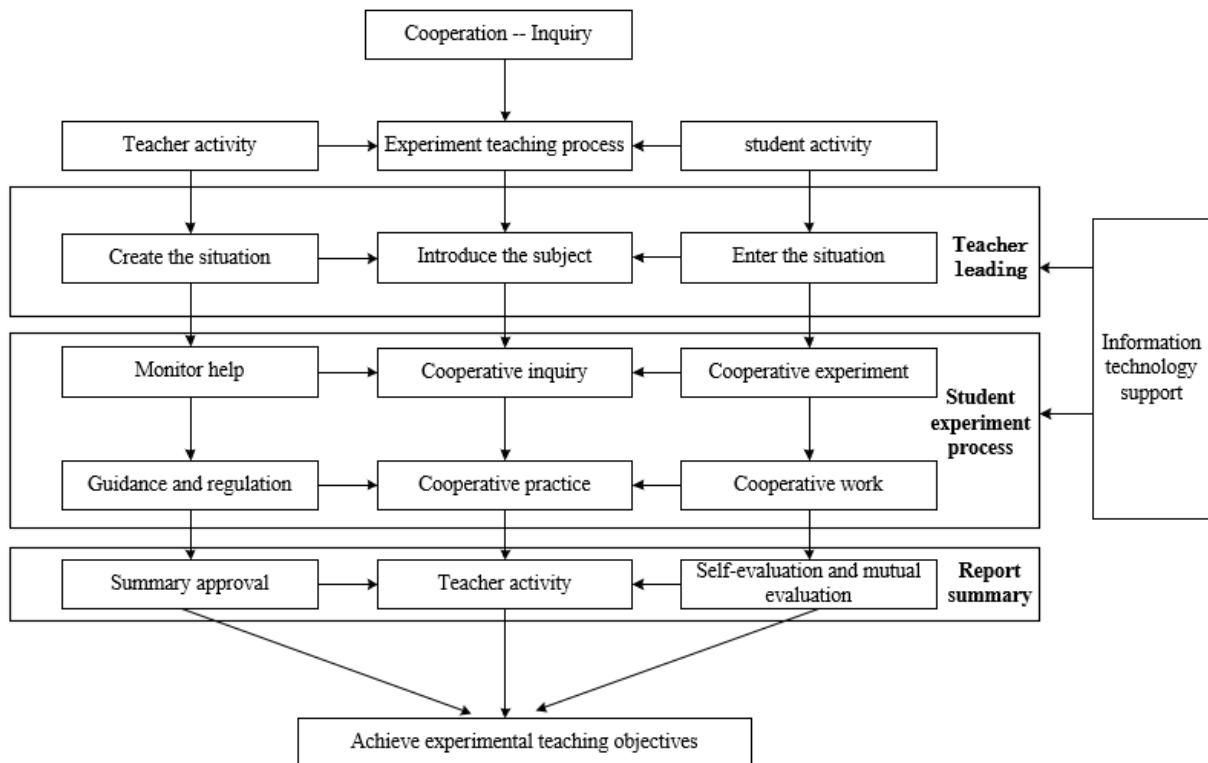


Figure 2: Experimental flow chart

The experimental process includes two aspects: the teacher's experimental guidance and the students' experimental activities. It is mainly carried out based on the clue of the experimental teaching process. Specifically, it includes:

1. Introduction of new lessons: the teacher uses courseware or other demonstration tools to demonstrate the operation and guide students into the experimental topic. At the same time, the teacher assigns experimental questions, demonstrates the methods of experimental operation, and puts forward precautions.
2. Cooperative exploration: students work in groups and set up experiments on the experimental platform according to the questions assigned by the teacher, and conduct exploratory experiments. In this link, the teacher only answers the questions raised by the students and does not "guide" the students' experiments.
3. Cooperative practice: This process should highlight the mutual learning and communication between students to achieve a "win-win" group learning.
4. Summary and communication: As a group, the group reports the situation of the experimental exploration to the teacher and classmates in the experimental class, and accepts questions and doubts from other students.

Finally, the teacher briefly evaluates the students' experimental situation based on the experimental objectives.

RESULTS AND DISCUSSION

Analysis Results Based on Data Perspective

Comparison of Academic Performance:

This study conducted a strictly controlled test on the two teaching classes before and after implementation. On the premise of ensuring that the test paper content was consistent and the test environment was exactly the same, a detailed statistical analysis was conducted on the test scores of the experimental class and the control class before and after the two tests. The results are shown in Table 1.

Table 1: The scores of the two classes before and after the experiment

	Stage	Average score	Standard deviation (Last 15 Students)	Eugenics rate	Pass rate
Experimental Class	Before the experiment	53.5	4.61	61.2	46.8
	After the experiment	72.5	3.68	64.3	54.0
Control class	Before the experiment	55.4	4.83	57.7	48.1
	After the experiment	62.6	5.11	60.6	48.2

from the data in Table 1 that after the experiment, the students in the experimental class performed significantly better than the control class. The experimental class not only has a higher average score, but also has a smaller standard deviation of the score distribution, which shows that while the overall level of students has improved, the learning effect is also more balanced. Although physics experiments only account for 15% of students' physics exams, through DVR technology, students' understanding of physical phenomena and laws has been significantly deepened, thus comprehensively improving the learning effect.

What is particularly noteworthy is that, from the performance statistics in Table 2, it can be seen that the performance of students in the experimental class has shown a substantial growth trend, and the number of students in low grades has significantly decreased. This result highlights an important advantage of this experimental activity: it effectively improved the performance of some underachievers and confirmed the positive transfer effect of DVR technology on basic physics knowledge.

Table 2: Statistics of students' final physics experiment test scores

Class	95 – 85	85 - 75	75-65	65-50	Under 50
Experimental Class	17	25	12	1	0
Control class	8	10	21	7	1

The Direct Impact of DVR Technology on Students' Cognition:

The experiment shows that DVR technology has a positive impact on the teaching of middle school physics experiments. The basic situation of the students in the experimental class is: from paying attention to the demonstration of DVR technology, to trying it by themselves, and finally being able to actively use DVR technology to solve physical problems. Compared with the control class, it can be seen that: first, the learning interest of the students in the experimental class has been significantly improved, and the students' confidence in solving problems has been significantly enhanced; second, the students' methods of solving physical problems have changed.

During the study, through classroom observations and post-class interviews, we found that about a quarter of the students in the experimental class gradually changed from their initial fear of physics learning to an interest in physics learning, and their confidence in learning was significantly enhanced. The experimental class also had a big change in the way they solved physics problems. They had a stronger sense of active exploration. Most students liked to think about problems from different perspectives and tried different input conditions. This was clearly reflected in the physics final exam. For example, in the final physics exam, there was a question like this:

- Analysis question: If the magnitude of two component forces is constant, is the magnitude of the resultant force also constant? Is the resultant force necessarily greater than the component forces? Then give the following question: Student, what methods can you choose when solving this problem?

After the test, it was found that the methods given by students involved the following five types, as shown in Table 3.

Table 3: Statistics of methods for solving physical problems

Class	Drawing method	Example calculation analysis	Hands-on Experiment	With physics learning software	Self-inference
Experimental Class	30	18	18	21	2
Control class	36	23	11	3	0

In particular, in the aspect of "using physics learning software to analyze and solve problems", the students of the two classes formed a sharp contrast. Almost all the students in the experimental class had experience in using the physics learning software "High School Physics 3D Laboratory" and also realized the advantages of using this learning software to solve problems.

Students with Different Knowledge Bases' Recognition of DVR Technology:

Based on the collected data, students were grouped based on their class rank, and their identification with the DVR laboratory was compared. Using SPSS V 24.0 was used for variance analysis test, and the conclusion shown in Table 4 was obtained under the condition of homogeneity of variances (Sig = 0.757).

Table 4: Analysis of variance for students with different knowledge levels

	Sum of squares	Degrees of freedom	Mean square	F	Significance
Between groups	17.976	3	5.992	3.866	.012
Within group	153.461	99	1.550		
Total	171.437	102			

From Table 4, Sig=0.012 < 0.05, which shows that there are significant differences between different categories. That is, from the perspective of knowledge base, students with different levels show significant differences in DVR room identification. In order to further explore the impact of the DVR room on students with different knowledge levels, the results shown in Table 5 were obtained through "post-hoc test -pairwise comparison".

Table 5: Comparative analysis of classification of students with different knowledge levels

	(I) Grade level		(J) Grade level	Standard error	Significance	95 % Confidence interval	
	average difference (IJ)					Lower limit	Upper limit
LSD	1.00	2.00	- 1.02295*	.33235	.003	-1.6824	-0.3635
		3.00	-0.26087	0.36714	0.479	-0.9894	0.4676
		4	-0.26501	0.37578	0.482	-1.0106	0.4806
	2	1	1.02295*	0.33235	0.003	0.3635	1.6824
		3	.76208*	0.33235	0.024	0.1026	1.4215
		4	.75794*	0.34187	0.029	0.0796	1.4363
	3	1	0.26087	0.36714	0.479	-0.4676	0.9894
		2	-.76208*	0.33235	0.024	-1.4215	-0.1026
		4	-0.00414	0.37578	0.991	-0.7498	0.7415
	4	1	0.26501	0.37578	0.482	-0.4806	1.0106
		2.00	- .75794*	.34187	.029	-1.4363	-0.0796
		3.00	.00414	.37578	.991	-0.7415	.7498

The results confirmed that students with category number 2 are significantly different from students in other categories, and their mean value is the highest. This shows that students with lower basic knowledge recognize the DVR room more, while top students with higher grades and grades There is no significant difference in the perception of the DVR room among the weaker students.

Discussion

The Cognitive Promotion Effect of DVR Technology on Students' Physics Learning:

DVR technology in physics experimental teaching reflects the paradigm shift of educational informatization. The virtual experimental environment constructed by this technology achieves high-precision simulation of macroscopic physical phenomena and significantly reduces systematic errors and random errors. This high-fidelity experimental environment helps students observe physical phenomena more accurately and verify physical laws, thus overcoming the problem of data deviation caused by instrument accuracy limitations and human operating errors in traditional experiments. At the same time, the introduction of DVR technology has caused a fundamental change in the experimental teaching model. It not only optimizes the allocation of teaching resources but also significantly improves students' cognitive engagement by creating an interactive and immersive learning environment. This innovative teaching method can effectively stimulate students' endogenous learning motivation [12] and improve their autonomy and initiative in the experimental learning process.

The Effect of DVR Technology on Students' Self-Efficacy in Physics Learning:

DVR technology provides students with a low-risk, high-control experimental platform, significantly improving the success rate of experiments. This technology creates a learning environment that allows students to conduct unlimited trials and errors, effectively reducing students' experimental anxiety and fear of failure. This low-threat, high-degree-of-freedom experimental environment is conducive to students establishing a positive attribution model and enhancing their internal control tendencies. Students can complete experimental tasks

more confidently, which not only improves their self-efficacy but also obtains positive emotional experiences [13] and promotes positive academic emotions.

DVR Technology's Differentiated Empowerment for Specific Learning Groups:
Enhance the Successful Experimental Experience of Students with Poor Hands-On Ability and Cultivate Self-Confidence in Physics Learning:

For students with poor experimental operation ability, the traditional physical experiment environment often has insurmountable barriers. The unfamiliarity of operation skills, the unfamiliarity of experimental equipment, and the potential worry about damage to expensive instruments often daunt such students, resulting in a significant reduction in the success rate of the experiment. The introduction of DVR technology is like a bridge, cleverly resolving these obstacles and creating a zero-pressure exploration environment for students. In this "digital experiment garden", students can calmly conduct various operation attempts, while improving the success rate of the experiment, and gradually build up experimental confidence and self-efficacy. More importantly, DVR technology breaks through the time and space barriers of traditional experiments and gives students full autonomy in their experiments. They can practice repeatedly according to their own pace, freely adjust various parameters, and deepen their understanding of the essence of the experiment through continuous exploration. As confirmed by Meng Xianghong's research, this innovative technology-assisted learning model has shown significant results in improving students' overall learning effectiveness [14].

Provide A Multi-Dimensional Physics Exploration Platform for Lower-Middle-Level Students to Stimulate Their Learning Potential:

In the practice of middle school physics teaching, even students with relatively poor academic performance still maintain a strong interest and enthusiasm for physics. However, the complexity of the traditional experimental environment often becomes a stumbling block for these students and brings them frustration. Due to the cumbersome experimental process and unstable data quality, it is difficult for these students to complete a successful physics experiment, let alone gain insight into physical laws from experimental data.

DVR technology provides a solution to this dilemma. This technology significantly simplifies the experimental process while greatly improving the accuracy and consistency of experimental data. For students whose physics scores are below average, providing them with a scaffolding means that they have more opportunities to experience the joy of successful experiments [15] and truly realize "discovery learning"[16]. This positive experience can effectively improve their self-confidence and learning initiative. From a holistic perspective, this technology-enabled learning model builds a more inclusive and supportive growth environment for students with learning difficulties. This change is not only reflected in the improvement of performance but also has a more profound significance: it reshapes these students' cognitive picture of physics learning, cultivates their lasting enthusiasm for exploring the mysteries of science, and gives them the confidence to face challenges head-on and courage.

Limitations of DVR Technology:

Potential Impact on Cultivating Students' Practical Operation Ability:

Whether it is a virtual reality environment that creates an immersive experience or a convenient and easy-to-use desktop virtual system, over-reliance on these technologies may cause students to drift away from real experimental operations. This kind of technology

dependence may not only weaken students' practical skills in the field of physical experiments but may also subtly eliminate their keen perception of the real experimental environment. From a long-term perspective, this trend may weaken students' adaptability and practical skills when facing real experiments. When encountering unpredictable emergencies in the real experimental environment, students who are overly immersed in the virtual environment often appear to be caught off guard and find it difficult to respond calmly. A longitudinal study on the effect of using virtual laboratories revealed that students who have been immersed in virtual experimental environments for a long time have a significant downward trend in their practical operation ability after returning to the real laboratory [17].

Students' Thoroughness and Rigor in Thinking During Experiments Have Declined:

Compared with the authenticity of traditional physical experiments, the experimental scenes presented by DVR technology tend to be idealized. Although this overly perfect experimental environment allows students to easily master the essentials of the experiment, it may invisibly deprive them of the opportunity to accumulate valuable experience by identifying and analyzing errors, and may even subtly inhibit their ability to generate innovative thinking. On a deeper level, because students lack intuitive perception and real experience of experimental equipment, methodology, and data during virtual experiments, it is very likely that their thinking in key links such as experimental condition control and data collection and processing will be superficial and difficult to achieve rigor. As scholar Chen Sufen's research reveals: the overly smooth setting, operation, and result acquisition process in virtual experiments can easily lead students to misinterpret scientific experiments as a smooth exploration process. This cognitive bias will undoubtedly form a potential obstacle to the cultivation of their critical thinking ability [18].

CONCLUSION AND SUGGESTIONS

This study builds a highly interactive DVR environment for learners by skillfully using the "High School Physics 3D Laboratory" software. Based on an in-depth analysis of the physics experiment goals and learner characteristics, a set of cooperative inquiry-based experimental teaching models was carefully designed and implemented. Through a progressive and step-by-step task sequence, the learning group is guided to make full use of the virtual reality environment and gradually carry out exploratory experiments. This method not only enables learners to summarize physical laws independently, but also enables them to develop a more systematic and in-depth understanding of relevant knowledge points. It is worth mentioning that this study uses groups as a unit to carry out inquiry-based learning, and uses collaborative learning theory as a guide to build an objective and standardized evaluation system. This method effectively promotes knowledge sharing and collaboration within the group, and at the same time significantly improves students' collaboration abilities during the learning process. More importantly, this learning model greatly enhances students' self-efficacy and innovative spirit, laying a solid foundation for them to assume corresponding roles in society in the future. It is true that DVR technology has cleverly overcome many drawbacks of traditional physics experiment teaching and has had a positive and far-reaching impact on students' physics learning. However, we should also be aware that as a teaching aid, DVR also has its inherent limitations. For example, the over-idealization of the virtual experimental environment may, to some extent, affect students' practical ability and the rigor of thinking about problems. This phenomenon is worth our deep consideration: in today's ever-changing technology, especially in the era of generative artificial intelligence reconstructing the educational paradigm, the

decreasing trend of students' hands-on practical ability has become an educational challenge that needs to be faced. Therefore, in teaching practice, a strategy of "combining virtual and real" should be adopted, that is, while making full use of the advantages of DVR technology, the value of traditional experiments should not be ignored. This balanced teaching method can help students understand the essence of experiments from multiple dimensions and deeply grasp the principles of physics. Through the organic integration of virtual and reality, we can build a three-dimensional, multi-level learning ecosystem for students, so that they can broaden their horizons and move forward solidly on the journey of physics learning.

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