Influence of Self-Regulated Strategy Development on the Performance of Virtual Reality-Based Teaching in Online Learning

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Abstract—Virtual reality technology has been fully integrated into the field of education. Such technology has become the focus of online learning that uses efficient and advanced virtual reality technology to improve the efficiency of learners. Online learning also gives full play to the characteristics of free learning time, flexible location, and free learning pace. Although online learning also easily leads to low efficiency due to physical isolation, it can effectively improve the performance of virtual reality-based teaching by using the self-regulated strategy development (SRSD) model. Based on this model, an experiment was conducted on online teaching course for first-year linguistics students of a provincial graduate school in China to test the influence of the model on the performance of virtual reality-based teaching in online learning. Results show that after the SRSD model, a significant difference is observed between pretest scores and post-test scores of graduate students in the experimental group ($t=-4.925$, $p=0.000$). A significant difference is observed between pretest self-regulation and post-test self-regulation of graduate students in the experimental group ($t=-7.505$, $p=0.000$). Finally, significant differences are observed between the experimental and control groups in the improvement of post-test scores and post-test self-regulation. Conclusions are of important reference value for enriching the application of the SRSD model in virtual reality-based teaching, improving the self-regulation ability of students, and improving the performance of learners by adopting a model more suitable for the characteristics of online teaching.

Keywords—online learning, self-regulated strategy development model (SRSD), virtual reality, experimental research

1 Introduction

The means of education informatization represented by emerging technologies such as virtual reality have fully penetrated online teaching, making online learning a good choice to overcome the time and space segmentation between teachers and learners. Especially during the COVID-19 pandemic, the vast majority of universities in China

have conducted online teaching, comprising teaching forms such as online live teaching, online video teaching, virtual reality-based teaching, and massive online open classes. The massive shift into online teaching leads to a lack of self-discipline or positive learning attitudes of students due to the virtual reality-based teaching environment. In the context of globalization, fully learning from information technology is necessary to strengthen cooperation in the field of education. Especially under the background of rapid development of the Internet, the concept of traditional teaching is also facing the effect of different educational concepts in different countries, and the demand for more efficient and personalized learning anytime and anywhere is increasing sharply.

To solve the problem of low efficiency in traditional teaching, creating and adopting various new teaching modes in online teaching, such as virtual reality-based teaching, as well as increasing the initiative and adaptability of schools to the development of online education, is necessary. At present, for online learning in various colleges and universities in China, more teachers provide detailed tasks for each class by using virtual reality-based teaching and require students to complete these specific tasks combined with unit themes, class design, and homework design. Then, the teachers gradually establish a knowledge system. However, because virtual reality-based teaching has been separated from the normal classroom teaching environment, the network channel makes introduces difficulties or even precludes teachers from effectively monitoring the learning status of students and providing feedback on their learning progress. The amount, difficulty, and length of teaching content may cause students to lose concentration in online learning.

As key talent resources in China's higher education system, the ability of many graduate students has not been completely improved due to the selection mechanism of graduate students in China. They lack self-efficacy and confidence, and put more emphasis on examination but cannot apply it to practical scenarios. Therefore, additional educational theories are needed to improve the ability of graduate students. In developed countries such as the United States and those in Europe, teachers built a rich teaching background with self-regulated strategy development (SRSD). They effectively promoted the interaction between teachers and students, as well as students and students, through methods such as group discussion, teacher demonstration, student memory, and peer support. They completed teaching tasks by constructing a scientific and reasonable teaching stage, improving the adaptability and flexibility of the entire teaching process.

SRSD mode teaching has a very clear process, which is fundamentally different from other types of cognition teaching modes. The SRSD mode allows students to correctly understand the teaching intention of teachers. Each teaching step has a very clear demonstration process so that learners can clarify the teaching objectives. Given that teaching under the SRSD mode emphasizes teacher-student interaction and student-student interaction, it can effectively solve the problem of low emotional input of learners in virtual reality-based teaching. Therefore, the emotional support of teachers and classmates can better promote the learning input of online learners. By adopting scientific teaching rules, learners can develop good learning rules, which can break through the subjectivity of the random daily learning of online learners so that they can more abide by the learning schedule in online learning. The SRSD mode has reasonable time

arrangements and progress requirements by considering the learning needs of different learning levels. Learners can arrange their learning times in accordance with factors such as their learning ability and cognitive input. They enter the next stage after achieving their learning goals in one stage. The adoption of the SRSD teaching mode in virtual reality-based teaching has a more extensive implementation space and application value.

Despite the wide use of SRSD in the educational practice of developed countries, it is not widely used in China. In particular, studies on how to adopt this SRSD for students in China are limited. Therefore, under the SRSD mode, teachers are the guide in the classroom. Through innovative teaching mode, such as virtual reality-based teaching, teachers can achieve efficient teaching guidance in online learning. They can also adopt appropriate teaching strategies to strengthen the interaction of virtual reality-based teaching, improve the performance of learners in the classroom, and promote the learning performance of online learners.

2 Literature review

The self-regulated development mode has been rapidly developed and widely applied since it was proposed by western scholars in the 1960s. In particular, the self-regulated development mode proposed by Graham et al. [1] plays a very important role. This theory has been studied in teaching abroad for more than 20 years. The SRSD teaching model is a high-quality teaching guidance model that is completed through six teaching stages. It mainly improves learners' mastery of knowledge through the construction of knowledge background, discussion, teacher demonstration, memory, support, and independent expression. SRSD can achieve self-regulation by allowing learners to strengthen the application of learning strategies. Although this theory was first proposed for the purpose of learning with disabilities, it also has been widely applied in other disciplines, along with the continuous improvement and enrichment of the theory.

Later, a large number of scholars conducted extensive research on the application of the SRSD model, especially abroad and in developed countries. Limpo et al. [2] performed a comparative experiment, in which a total of 109 students received planning guidance based on the SRSD model, while 83 students received standard teaching guidance. The results showed that the students who adopted SRSD could write longer and better articles than could those students in the control group. Graham et al. [3] demonstrated that the SRSD model could make collaborative strategies clearer and more standardized, and they suggested that speech-language pathologists should apply the SRSD model to children with teaching difficulties. Gillespie et al. [4] indicated that the implementation of the SRSD teaching model can provide a better learning experience for students with autism and improve their learning effectiveness. McKeown et al. [5] found that SRSD can effectively improve the learning emotions of learners and skills of students with emotional and behavioral disorders (EBD). Chen et al. [6] demonstrated the effectiveness of SRSD in promoting the development of students' review ability. Ray et al. [7] used the SRSD model to study the effectiveness of argumentative

teaching for the ACT for senior high school students with disabilities or students at risk of learning difficulties. Their results showed that the SRSD model could effectively improve the effect on students' learning process.

McKeown et al. [8] found that students have a higher recognition of SRSD. Peltier et al. [9] demonstrated that the SRSD model plays an obvious role in improving the learning effect of learners in reading, writing, and mathematics. Harris et al. [10] showed that when teachers implemented SRSD teaching, the performance of students' learning in the story and opinion articles had significant and meaningful changes. Teachers and students believed that SRSD had social validity. Santangelo et al. [11] used SRSD to conduct a case study on teaching story grammar strategies to fifth-grade students. They found that students who received SRSD significantly improved their skills. Graham et al. [12] demonstrated that SRSD teaching also improved the knowledge of students. Peer support could also enhance SRSD teaching by increasing the planning knowledge of students and improving their generalization ability in information and narrative learning. Zumbrunn et al. [13] analyzed the effectiveness of the SRSD teaching mode on the learning skills and knowledge of six first-grade students. They found that SRSD is beneficial to their learning, and their knowledge has been significantly improved.

Sexton et al. [14] believed that SRSD has an obvious effect on promoting the learning level of students with learning difficulties. Miller et al. [15] indicated that the SRSD teaching mode improved the overall learning performance of students in opinion articles. Zito et al. [16] found that the SRSD teaching mode plays an important role in improving self-regulation and learning strategies for students with excellent academic performance. Baghbadorani et al. [17] adopted SRSD and non-SRSD models in two universities. They found that the SRSD model could significantly improve persuasive learning ability. Harris et al. [18] found a significant effect on improving learning ability in more complete, longer, and better learning through the application of SRSD in teaching strategies to students with attention deficit hyperactivity disorder. Ennis et al. [19] believed that SRSD is a teaching method that has been proved successful for students with EBD. They found a functional relationship between SRSD teaching and the learning performance of students, which could be measured by summarizing elements, quality, and total words.

Schneider et al. [20] conducted a comparative test on the learning skills of four boys with Asperger's syndrome. They found that SRSD can significantly improve the fluency and quality of learning. Hagaman et al. [21] believed that SRSD is the mainstream model to address the learning ability of students at different levels and improve their learning levels of students. The results of Asaro-Saddler et al. [22] demonstrated that SRSD methods can significantly improve learning quality, and older students can benefit more from the intervention. Popham et al. [23] proved the effectiveness of SRSD reading intervention for disabled students in a school environment.

Virtual reality is a computer environment that helps users create a virtual world and obtain simulation experience. It gives users an immersive interactive experience. The sense of presence obtained through immersion is a main driving force for the application of virtual reality in teaching. In virtual reality-based teaching, virtual reality can simulate the unreachable scenes in the real world, enable learners to participate in the

virtual observation and natural interaction of abstract concepts, and improve learners' cognition and understanding of abstract things. Virtual reality has a good application prospect for teaching form innovation

The literature shows that based on extensive teaching studies, many scholars had carried out many relevant studies to continuously improve SRSD. These studies combined different learning styles and strategies, widely connected cognitive factors of students, and considered different objects at different age levels [24-25]. However, empirical studies on how to use the SRSD model efficiently in virtual reality-based teaching are extremely limited. Therefore, this study chose the SRSD model, which has an extensive research foundation, to conduct research on the teaching of graduate students, aiming to accumulate more empirical research materials for the SRSD model and expect to have certain guiding significance for improving the virtual reality-based teaching of students.

3 Methodology

Based on the SRSD model, this study scientifically analyzed the performance of virtual reality-based teaching of postgraduates with or without the SRSD model. Quantitative analysis of collected data was performed using the statistical software SPSS 22.0, including independent sample T-test, correlation analysis, and paired sample T-test [26].

3.1 Research objects

This study used samples of first-grade graduate students majoring in linguistics from Guangzhou Institute of Technology in China. This experiment comprised two classes, of which one was an experimental class and the other was a control class. To increase the reliability of the experimental results, the members of the research group undertook the teaching work in two classes: an experimental class and a control class.

3.2 Research steps

The course "Business communication" for graduate students majoring in linguistics was used as a score marker. In this course, virtual reality technology was used to simulate a real business negotiation environment. A self-regulated questionnaire was used to obtain the score. Course scores and self-regulated scores were converted into the range of 0-100 points. The research steps are as follows. The first step is the pretest of learning performance and self-regulation. The students were randomly divided into classes when they entered school. To increase the reliability and validity of this experiment, they must conduct a pretest on their course scores and self-regulation to test whether significant differences occurred in "Business communication." The independent sample T-test was performed on the data results.

The second step is the teaching experiment. The SRSD mode was used in the experimental class, and the conventional virtual reality-based teaching mode was used in the

control class. The experimental and the control groups underwent the virtual reality-based teaching of the "Business communication" course for eight weeks. Afterward, the post-test was conducted. This study performed a self-regulated questionnaire and test for the experimental group and the control group again by using the two-paired sample T-test method.

4 Results analysis

4.1 Pretest scores and pretest self-regulation

Table 1 shows that the t-test (independent sample t-test) was used to study the difference between two items of pretest scores and pretest self-regulation. The table shows no significant differences in pretest scores and pretest self-regulation for all different samples (p>0.05). This finding means that all different samples are consistent in the pretest scores and pretest self-regulation without any difference. Therefore, the scores and self-regulation ability in the experimental and control classes before the experiment were at the same level, ensuring the consistency of subjects with those before the experiment without any individual differences.

Table 1. Pretest scores and pretest self-regulation

Items	Groups	Sample size	Average	Standard deviation	Mean difference	D-value 95% CI	*t*	*df*	*p*
Pretest scores	Control	25	70.86	5.76	0.29	-3.195 ~ 3.779	0.168	48	0.867
	Experiment	25	70.57	6.48					
	Total	50	70.72	6.07					
Pretest self-regulation	Control	25	70.41	7.13	-1.3	-5.687 ~ 3.095	-0.593	48	0.556
	Experiment	25	71.7	8.27					
	Total	50	71.06	7.67					

$^{*}p$<0.05, $^{**}p$<0.01

4.2 Correlation analysis

This experiment investigated the following three aspects: 1. whether a correlation exists between learning performance and self-regulation, 2. whether a significant difference exists between the SRSD and conventional teaching models on the influence of students, and 3. whether a significant difference exists between the experimental and control groups in self-regulation ability after adopted different teaching modes.

Table 2 shows that the correlation coefficient between pretest score and pretest self-regulation was 0.981 and had a significant difference at 0.01. Thus, a significant positive correlation was found between pretest scores and pretest self-regulation. The correlation coefficient between post-test score and post-test self-regulation was 0.976 and had a significant difference at 0.01. Thus, a significant positive correlation was observed between post-test scores and post-test self-regulation.

Table 2. Correlation coefficient

Pearson	Pretest score	Pretest self-regulation	Pearson	Post-test score	Post-test self-regulation
Pretest score	1	-	Post-test score	1	-
Pretest self-regulation	0.981**	1	Post-test self-regulation	0.976**	1

*p<0.05, **p<0.01

4.3 Paired sample T-test

Table 3 shows a significant difference between the pretest and post-test scores of students in the control group at 0.05 (t=−2.520, p=0.019). The average value of the pretest score (70.48) was significantly lower than that of the post-test score (75.52). A significant difference was found between pretest self-regulation and post-test self-regulation in the control group at 0.01 (t=−4.494, p=0.000), and the average value of pretest self-regulation (69.28) was significantly lower than that of post-test self-regulation (77.36).

Table 3. The paired t-test analysis result

Group	Item	Pair (average value ± standard deviation)		D-value (Pair 1-Pair 2)	*t*	*p*
		Pair 1	*Pair 2*			
Control group	Pretest score vs Post-test score	70.84± 5.70	75.52± 6.17	-4.68	-2.52	0.019*
	Pretest self-regulation vs Post-test self-regulation	69.28± 6.01	77.36± 6.10	-8.08	-4.494	0.000**
Experimental group	Pretest score vs Post-test score	70.56± 6.52	79.48± 6.35	-8.92	-4.925	0.000**
	Pretest self-regulation vs Post-test self-regulation	67.96± 7.04	82.16± 6.46	-14.2	-7.505	0.000**

*p<0.05, **p<0.01

A significant difference was observed between the pretest and post-test scores in the experimental group at 0.01 (t=−4.925, p=0.000), and the average value of the pretest score (70.56) was significantly lower than that of the post-test score (79.48). A significant difference was found between pretest self-regulation and post-test self-regulation in the experimental group at 0.01 (t=−7.505, p=0.000), and the average value of pretest self-regulation (67.96) was significantly lower than that of post-test self-regulation (82.16).

In findings, the paired sample T-test results showed a significant difference in terms of the improved range of post-test results and pretest results of score and self-regulation ability in the control group (p<0.05) after eight weeks each of different modes of virtual reality-based teaching in online learning. The results of the experimental group were

the same as those of the control group, indicating that the traditional models and SRSD models play an important role in promoting virtual reality-based teaching. The post-test scores of the students in both classes have been improved compared to pretest scores, indicating that the virtual reality-based teaching guidance of students in both classes is helpful to improve their scores. Compared with the control class, the scores of the SRSD experiment class have been improved more, indicating a significant difference.

Direct and clear guidance on the virtual reality-based teaching process of students can greatly help to improve the ability of students. The main reason for this finding is that, through the guidance of the SRSD model, students could have a better understanding of the virtual reality-based teaching process required by teachers and better regulate their learning process so that they can skillfully use strategies to ensure learning quality. In addition, the strategy guided by the SRSD model provides learners with a learning blueprint. Learners can make full use of the blueprint, gradually promote it according to the teaching mode, and complete tasks one by one during the process. Compared with the traditional virtual reality-based teaching mode, students had a more detailed understanding of their learning process, and they could use strategies to improve their learning level, Students are the core of the whole learning process, turning the virtual reality-based teaching by teachers into a learning process for students. Teaching responsibility can be transferred from being purely from teachers to students themselves, inspiring learning initiative and the desire of learners for knowledge.

In the process of gaining comprehensive learning skills, students can not only undertake responsibility purely but also enjoy many benefits. Under the SRSD model, the whole learning process focuses on the needs of students, from paper structure analysis to teacher demonstration and then to mutual discussion with classmates. Therefore, the whole teaching link could meet the demands of students, fundamentally improving their learning enthusiasm.

4.4 Difference between post-test self-regulation and post-test score

Table 4 shows that all post-test scores in the experimental and control groups were significant ($p<0.05$), meaning that different teaching methods have different post-test scores. Different teaching modes had significant effects on post-test scores at 0.05 ($t=-2.237$, $p=0.030$). The average value of post-test scores in the control group (75.52) was significantly lower than that in the experimental group (79.48). All post-test self-regulation in the experimental and control groups was significant ($p<0.05$). This finding indicates that different teaching methods have different post-test self-regulation at 0.01 ($t=-2.786$, $p=0.008$), and the average value of post-test self-regulation in the experimental group (82.61) was significantly higher than that in the control group (77.08). Therefore, the two models can promote students, but the SRSD model is superior to the conventional model. The main reason for this result is that learners can make full use of the time before class to accumulate knowledge and make preliminary preparations for class tasks under the SRSD model.

Table 4. Difference between post-test self-regulation and post-test score

	Classification (average value ± standard deviation)		*t*	*p*
	Control (n=25)	*Experiment (n=25)*		
Post-test score	75.52±6.17	79.48±6.35	-2.237	0.030*
Post-test self-regulation	77.08±6.27	82.16±6.62	-2.786	0.008**

*p<0.05, **p<0.01

During the process of virtual reality-based teaching, learners can effectively realize self-regulation and adopt more suitable learning strategies for learning practice. Through the reasonable arrangement of time, scientific development of learning objectives, and increased consistency with teaching plans, learners can carry out self-evaluation more automatically after the completion. Teacher evaluation and peer mutual evaluation will also encourage learners to check whether they have mastered learning skills.

5 Teaching implications

5.1 Strengthen self-regulation of learners and adopt appropriate learning strategy

Virtual reality-based teaching is a complex process involving planning before teaching, adjustment during teaching, and modification after teaching. In the actual virtual reality-based teaching process, students, especially those with poor learning skills, often ignore the planning before learning stage and abandon the modification after learning stage. They also lack an understanding and good control over the whole virtual reality-based teaching process. In online teaching classes, students understand the problem of the composition with the help of teachers, but they often cannot correct their problems in the next composition and repeat their mistakes. Therefore, teachers work hard but students gain less knowledge. Virtual reality-based teaching guidance based on the SRSD model teaches students to use strategy, gives students enough opportunities to exercise, transfers the responsibility of improving learning to students themselves, constantly improves their online learning methods, and increasingly increases their sense of self-efficacy.

5.2 Encourage the interaction between teachers and students as well as students and students to promote emotional communication

In traditional virtual reality-based teaching, teachers often cannot take good care of the learning needs of students. Some of them lack real guidance. Often, virtual reality-based teaching classes are turned into the computer game. Some teachers are more eager to imbue students with knowledge and skills, but they cannot take care of the needs of students. Here, students have not fully mastered such a strategy and cannot use virtual reality scientifically. Therefore, online teaching classes should make full use of

teacher-student interaction and student-student interaction, giving students enough opportunities to confirm their understanding of classroom content with teachers and peers. Such an approach can effectively improve the efficiency of virtual reality-based teaching in online learning. The SRSD model puts more emphasis on help from peers and teachers. Especially in the demonstration and discussion stage, students can learn considerably from peers and teachers and further stimulate their learning motivation.

5.3 Encourage learners to explore their personalized learning methods

Virtual reality-based teaching in online learning is a complex process and requires the full participation of different roles. The teaching guidance of the SRSD model requires that teachers give different types of help to different students in virtual reality-based teaching. Learners should also have the opportunity to seek help from peers and strengthen their interaction with their peers. To better evaluate the learning status of students, the SRSD teaching model supports students and teachers to truly control the learning process through establishing archives and other diversified ways. They can also use learning records to analyze the learning effect of different learners. In particular, in virtual reality-based teaching, the integration of the SRSD model with big data technology can help students to achieve the teaching goals and see their progress, improve their enthusiasm for learning, and finally improve their scores.

6 Conclusion

Virtual reality-based teaching is not only diversified but also updated in real-time. Students can master the latest learning materials and actively participate in the search and selection of learning resources under the instruction of teachers. Thus, virtual reality-based teaching in online learning becomes the mainstream mode in the context of the current epidemic. Owing to the spatial separation between teachers and students as well as students and students in virtual reality-based teaching in online learning, learning performance has attracted considerable attention. The learning performance of learners can be effectively improved with the SRSD model. Based on the SRSD model, this paper experimented with first-grade linguistics students in a provincial graduate school in China to test the influence of the SRSD model on the performance of virtual reality-based teaching in online learning. The results showed that the course score and self-regulation ability of students in the experimental and control groups have been improved. However, the degree of improvement in these two aspects was significantly different between the two groups. Further research is suggested to be made on the influence of the SRSD model on self-efficacy, thinking ability, and application of learning strategy of students.

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