Feasibility Analysis of Visual Interaction Mode in Digital Art Design Teaching

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Abstract—The visual presentation of teaching contents facilitates students to master the relevant knowledge and skills of digital art design (DAD). The existing studies focus on the construction of traditional classroom teaching and interaction strategies, but rarely tackle the visual interaction (VI) technology of synchronous online classroom. This paper analyzes the feasibility of VI mode in DAD teaching. Firstly, the authors detailed the realization steps for teacher-student VI in the DAD teaching process control platform, and constructed the topology of VI system in DAD teaching. After a data analysis on VI flow, the authors parsed the VI flow data, and encoded the teacher-student VI involved in DAD teaching. Based on the improved neural network, a model was established to predict the degree of realization for course goals of DAD teaching. Through experiments, the teacher-student VI in DAD teaching was described statistically, and the relevant analysis results were obtained, which verify the effectiveness of our prediction model.

Keywords—visual interaction (VI), digital art design (DAD), feasibility analysis

1 Introduction

The effectiveness of teacher-student interaction directly affects the effect of classroom teaching [1-8]. The visualization of text, image, and video data has been widely applied in various industries and social groups, and can be introduced to the teaching of design courses [9-15]. Compared with traditional offline classroom, the synchronous online classroom of digital art design (DAD) involves highly complex teacher-student interactions. It is extremely difficult to realize high-quality teaching in the virtual scenario [16-20]. The visual presentation of teaching contents facilitates students to master the relevant knowledge and skills of DAD. To apply and promote visual interaction (VI) mode to DAD teaching, it is important to observe the records, process, interaction problems, and causes of these problems of DAD course teaching.

Massive open online courses (MOOCs) lack the sense of immersion. To solve the problem, Zhang et al. [21] explored the key techniques, constructed an interactive MOOC system based on virtual reality (VR), and improved the system to enhance the immersive and interactive feelings of users in virtual scenes. Qi [22] introduced a case study on providing an interactive and collaborative environment for remote teaching, reviewed the existing multi-user collaboration environments, summarized the requirements of supporting remote teaching with collaborative environment, and analyzed how the open platform of Wonderland satisfies these requirements. It was learned that such an environment fully supports the entire learning process. Open educational resources (OER) have been successfully applied to teaching challenging disciplines. Cacho et al. [23] proposed a new virtual memory teaching method, which simulates the main elements of the memory hierarchy, and described the classroom plan and its application in OER Amnesia. The results show that the improvements of up to 180% in scores of students when they use Amnesia to learn virtual memory. Tourou et al. [24] discussed the current development trend of e-learning, such as virtual experiments and remote experiments in electronic engineering education, introduced a network-based wind energy conversion and control learning module, detailed graphic user interface and experimental operations, and talked about different learning goals and interaction possibilities. Ding and Li [25] proposed an interactive teaching mode based on the Proteus virtual laboratory. This teaching model helps stimulate students' learning interest, improve their learning efficiency and practical ability, and promote the teaching curriculum reform of single-chip machines.

The existing studies on teaching interaction emphasize the construction of traditional classroom teaching and interaction strategies over the VI technology of synchronous online classroom. Therefore, this paper analyzes the feasibility of VI mode in DAD teaching. The main contents are as follows: (1) Detailing the realization for teacher-student VI in the DAD teaching process control platform; (2) Constructing the topology of VI system in DAD teaching; (3) Analyzing the data of VI flow, and encoding the teacher-student VI involved in DAD teaching; (4) Building a prediction model for the degree of realization for course goals of DAD teaching, based on the improved neural network: the realization degree was predicted with teacher-student VI behaviors VI1-18 as the model inputs. Finally, experiments were carried out to describe the teacher-student VI in DAD teaching statistically, produce the relevant analysis results, and verify the effectiveness of our prediction model.

2 VI realization

In DAD teaching, the VI aims to display the design process and aesthetic laws of many aspects of DAD, including design environment, visual principles, application range, and basic elements, to students via the visual system. On the DAD teaching process control platform, the visual display of DAD results is the goal for the transmission and conversion of teacher-student interaction information. Facing different types of student needs, the teaching process control platform properly presents the DAD images recommended by teachers. Then, the students feed back the acquired information to teachers and the platform, wrapping up the teaching process control. Figure 1 shows the topology of the VI system in DAD teaching. This paper details the realization steps of teacher-student VI on DAD teaching process control platform.

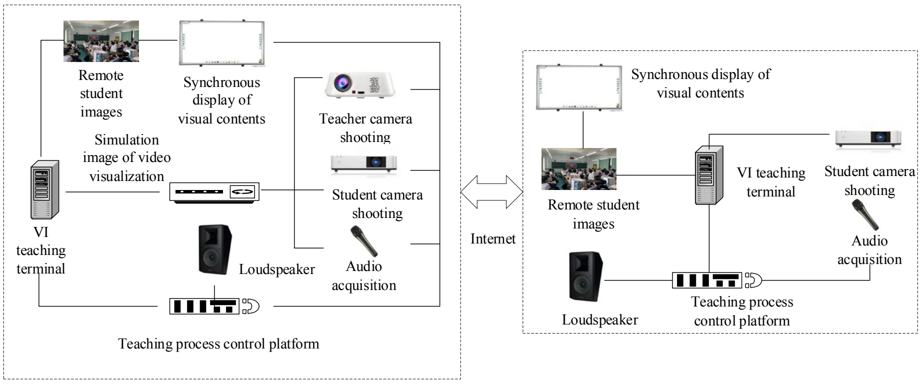

Fig. 1. Topology of VI system in DAD teaching

During DAD teaching, there are many kinds of image data requiring teacher-student VI. If the visual contents (e.g., tables, images, videos, and three-dimensional (3D) models) are selected blindly, it would be impossible to establish effective teacher-student VI, but impede the teaching process. Thus, it is important to choose the visual contents properly, according to the personalized needs of students. The contents can be selected and classified using the mind map, after analyzing the functions and applicable scenarios of mainstream visual presentation techniques.

To visualize DAD teaching process, it is necessary to analyze the students' interaction needs during DAD teaching, and complete VI according to the personalized needs of the students. This section defines several subjects in DAD teaching, including students, platform administrators, and teachers, and completes VI in the light of the VI needs of each kind of subjects.

To realize coordinated, efficient cooperation between students, platform administrators and teachers, this paper groups the students by interaction needs, and designs the visual display of images for each group. The grouping improves the display effect and accuracy. From the angle of teaching process, a complete DAD teaching process should begin with the teachers' definition of DAD teaching goals, and preparation of global teaching plan for the goals. Based on each link of the global teaching plan, phased teaching goals should be determined, and specific classroom teaching plans should be formulated. The students participate in the teaching process, and enter VI with teachers and other students. In this way, they learning the relevant knowledge of DAD, and acquire the ability to complete DAD independently. The students' evaluation of VI teaching provides a reference for platform administrators and teachers to management and push information, and reflect on teaching.

For DAD teaching process control, an important step is to display the key visual contents of DAD teaching process. The key visual contents of teaching should be determined, according to the specific needs of each student group.

Platform administrators intend to grasp the overall DAD teaching process, and recommend visual contents more accurately, such that the students in different groups can learn with the least difficulty. Institutive visual images should be presented directly to illustrate the steps of DAD. To implement VI, platform administrators need to fulfil three tasks: visualization of overall teaching progress, visualization of the completion degree of teaching goals, and the execution flow of the platform.

During the VI, teachers attempt to teach the relevant knowledge of DAD, and know the level of knowledge mastery of students through the interaction. Based on the interactive performance and evaluation of students, the teachers should adjust the execution of DAD teaching process. To implement VI, teachers need to visualize teaching traces, and visualize DAD tasks.

3 Data analysis on VI flow

This paper mainly analyzes the VI data on the platform, including the students' mastery of DAD knowledge, degree of realization of teaching goals, and execution progress of DAD teaching. The VI data were collected from DAD teaching, and preprocessed before being entered into the evaluation matrix.

Suppose there are *m* teaching links $X_i(0<i<=m)$. The score proportion of X_i in the DAD course is denoted as P_i. Each teaching link X_i contains *s* items $X_{ij}(0<j<=s)$. The score that should be obtained on each item is denoted as B_{ij}. Let *g* be the goals of the DAD course. The goal of each teaching link is denoted as Y_n. Then, the proportion of goal Y_n in each item of teaching link X_i is denoted as S_{ijn}. The actual score of students for each item of teaching link X_{ij} is denoted as A_{ij}. The actual total score of goal Y_n in teaching link X_i is denoted as A_{ni}. The score that should be obtained on link X_i is denoted as R_{ni}. The realization degree of the goal of link X_i, and that of the overall goal are denoted as U_{ni}, and U_n, respectively. Then, we have:

$$R_{ni} = \sum_{j=1}^{s} B_{ij} O_{ijn} \quad (1)$$

$$A_{ni} = \sum_{j=1}^{s} A_{ij} O_{ijn} \quad (2)$$

$$U_{ni} = \frac{A_{ni}}{R_{ni}} \quad (3)$$

$$U_{ni} = \frac{\sum_{i=1}^{m} A_{ni} P_i}{\sum_{i=1}^{m} R_{ni} P_i} \quad (4)$$

The realization degree of DAD teaching goals can be solved by the above formulas. To solve the overall realization degree of DAD course goals, the realization degrees of all students corresponding to the preprocessed data should be averaged. Then, the behaviors of the students with weak interests in VI and low realization degree of DAD course goals were mined and analyzed to identify the problematic teaching links, in order to improve the VI contents and modes. The flow of VI data analysis is displayed in Figure 2.

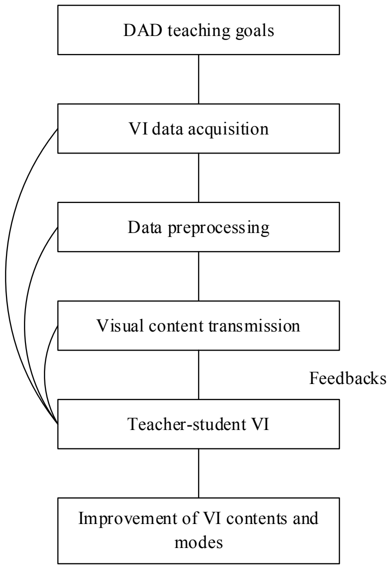

Fig. 2. Flow of VI data analysis

This paper encodes the teacher-student VI behaviors involved in DAD teaching. The following VI behaviors of teachers were encoded as VI1-8: acknowledgement of student performance, praise of student performance, acceptance of interaction request, raising questions about visual contents, raising summative questions, explaining visual contents, guiding the understanding of visual contents, and criticizing student performance. The following VI behaviors of students were encoded as VI9-13: collective response to teacher interaction, active individual response to teacher interaction, passive individual response to teacher interaction, raising questions about visual contents, and participating the themed discussion of visual contents. The following non-interactive course states were encoded VI14-16: chaotic state, student reflection or autonomous learning, and DAD practice. In addition, the following VI techniques were encoded VI17-18: teacher operation technology, and student operation technology.

Then, the proportion of verbal behaviors in teachers' VI can be calculated by:

$$\delta_1 = \frac{\sum_{i=1}^{8} VI_i}{\sum_{i=1}^{13} VI_i} \tag{5}$$

The proportion of raising questions in teachers' VI can be calculated by:

$$\delta_2 = \frac{\sum_{i=4}^{5} VI_i}{\sum_{i=1}^{13} VI_i} \tag{6}$$

The proportion of lecturing in teachers' VI can be calculated by:

$$\delta_3 = \frac{VI_6}{\sum_{i=1}^{8} VI_i} \tag{7}$$

The proportion of raising questions about visual contents in teachers' VI can be calculated by:

$$\delta_4 = \frac{VI_4}{VI_4 + VI_5} \tag{8}$$

The proportion of raising summative questions in teachers' VI can be calculated by:

$$\delta_5 = \frac{VI_5}{VI_4 + VI_5} \tag{9}$$

The ratio of indirect effect to direct effect in teachers' VI can be calculated by:

$$\delta_6 = \frac{\sum_{i=1}^{5} VI_i}{\sum_{i=6}^{8} VI_i} \tag{10}$$

Then, the proportion of verbal behaviors in students' VI can be calculated by:

$$\delta_7 = \frac{\sum_{i=9}^{13} VI_i}{\sum_{i=1}^{13} VI_i} \tag{11}$$

The proportion of non-interactive course states can be calculated by:

$$\delta_8 = \frac{\sum_{i=14}^{16} VI_i}{\sum_{i=1}^{13} VI_i} \tag{12}$$

The proportion of VI technology usage can be calculated by:

$$\delta_9 = \frac{VI_{17} + VI_{18}}{\sum_{i=1}^{13} VI_i} \tag{13}$$

4 Prediction of VI feasibility

Figure 3 shows the flow of VI feasibility prediction. This paper combines the multiple factors affecting the realization of course goals of DAD teaching, and establishes a prediction model for the realization degree of these goals. The teacher-student VI behaviors VI1-8 were imported to the model, in order to predict the realization degree of course goals of DAD teaching.

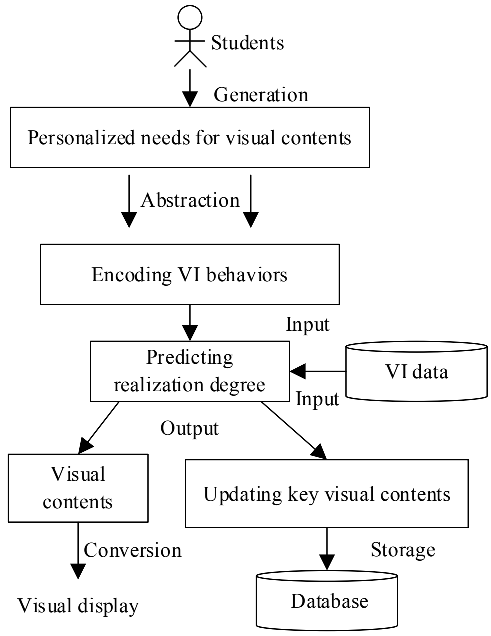

Fig. 3. Flow of feasibility analysis

VI has many common features with traditional teacher-student interaction, and differs with the latter in many respects. This paper explores the relationship between 18 factors and the realization degree of course goals of DAD teaching. Our neural network consists of an input layer, an output layer, and a hidden layer. The different layers are connected in one direction by nodes. Let g be the nonlinear activation function; w be the threshold of nodes. Then, the hidden layer output can be modeled by:

$$P_j = g\left(\sum Q_{ij} \times A_i - w_j\right) \tag{14}$$

The output layer output can be modeled by:

$$B_l = g\left(\sum E_{jl} \times P_j - w_l\right) \tag{15}$$

Sigmoid function was selected as the activation function:

$$g(a) = 1/\left(1 + e^{-a}\right) \tag{16}$$

Let e_{oi} be the expected output of node i; P_{oi} be the output corresponding to i. The error between expected output and calculated output can be expressed as:

$$T_o = 1/2 \times \sum \left(e_{oi} - P_{oi}\right)^2 \tag{17}$$

Let ω_{ij} be the weight matrix between the nodes on the lower layer and the nodes on the upper layer. The learning process of the neural network can be viewed as a setting and error correction of ω_{ij}. Let f be the learning factor; Ψ_i be the calculation error of output node i; P_j be the calculated output of output node j; β be the momentum factor. Then, the self-learning model of the neural network can be expressed as:

$$\Delta\omega_{ij}\left(m+1\right) = f \times \Psi_i \times P_j + \beta \times \Delta\omega_{ij}\left(m\right) \tag{18}$$

5 Experiments and results analysis

To effectively enhance the teaching effect, the key links of DAD teaching include stimulating the learning interest, and attracting the students to the visual contents. Figure 4 summarizes the visual modes preferred by students. It can be seen that the students prefer visual contents like tables, images, videos, and 3D models. The pure text form of traditional teaching mode can no longer meet the needs of DAD learners. On the display of DAD results, 3D models are more likely to attract the attention of students than two-dimensional (2D) images, which are not so realistic and stereo. Using 3D models, the students can understand the DAD process clearly, and comprehend DAD knowledge more profoundly, rapidly, and efficiently. This further demonstrates the necessity of applying VI technology in DAD teaching.

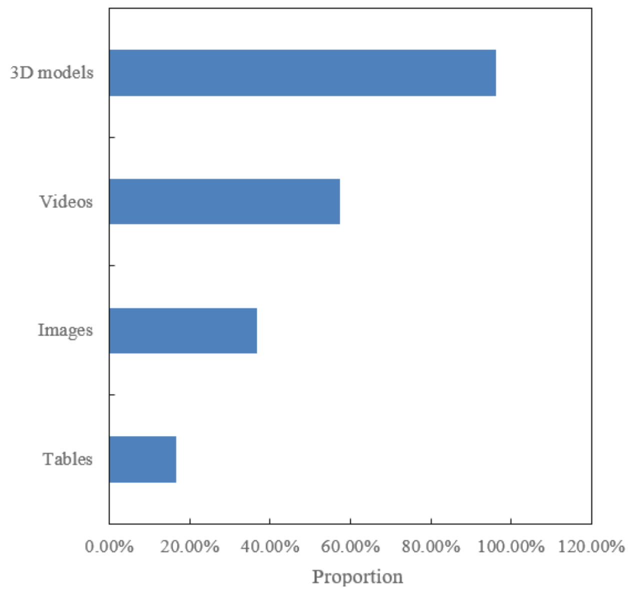

Fig. 4. Summary of visualization modes preferred by students

The overall teacher-student VI behaviors involved in DAD teaching were statistically analyzed as shown in Table 1.

Table 1. Descriptive statistics on VI behaviors

Variables	Symbols	*N*	Minimum	Maximum	Mean	Standard deviation	Variance
Teacher interaction	*VI*1	98	0	8	3.25	1.147	1.025
	*VI*2	93	2	4	3.04	1.326	1.686
	*VI*3	92	4	6	3.62	1.528	1.928
	*VI*4	92	2	4	3.29	0.741	1.360
	*VI*5	96	6	8	3.17	1.306	1.092
	*VI*6	93	4	6	3.07	1.852	1.825
	*VI*7	97	2	4	3.64	1.936	1.637
	*VI*8	95	3	5	3.92	0.792	1.924
Student interaction	*VI*9	97	0	3	3.85	1.629	1.147
	*VI*10	91	3	5	3.67	1.043	1.624
	*VI*11	98	5	7	3.81	1.205	1.052
	*VI*12	99	5	7	3.37	1.362	1.811
	*VI*13	94	1	4	2.62	1.084	1.637
Non-interactive class states	*VI*14	98	2	5	3.84	1.629	1.059
	*VI*15	95	5	7	3.22	1.311	1.102
	*VI*16	93	3	6	3.06	1.742	1.772
VI technology	*VI*17	93	3	5	3.37	1.148	1.258
	*VI*18	96	4	8	3.94	1.354	1.179

The mean represents the frequency of teacher-student interaction. The greater the mean, the more frequent the interaction. The standard deviation shows the difference between teachers and students concerning different interaction behaviors. The greater the standard deviation, the greater the difference between different interaction behaviors. The inverse is also true. As shown in Table 1, only a few teacher-student interactions had a mean smaller than 3. The standard deviation and variance of every teacher-student interaction were greater than 1. Therefore, different subjects have certain differences in selecting VI behaviors during DAD teaching.

This paper not only observes the VI state of a single student, but also collects the VI data of all students. Thus, the VI states of all students were plotted as shown in Figure 5.

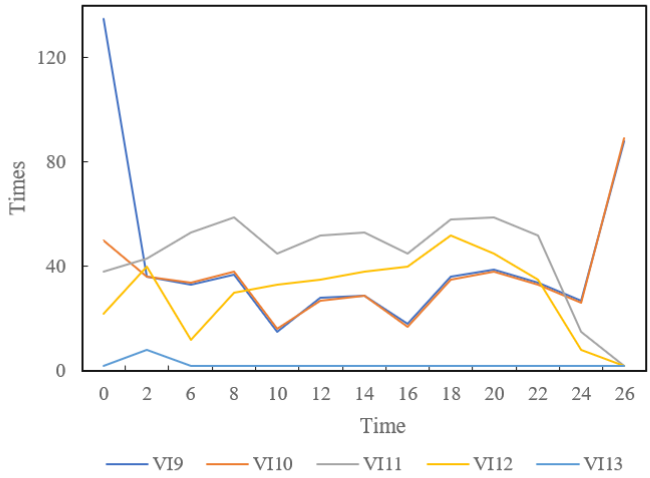

Fig. 5. VI states of students

In addition, the teacher-student VI behaviors of the subjects were subjected to descriptive statistical analysis. The teacher-student VI behaviors were classified into specific types to illustrate the students' behaviors like collective response to teacher interaction, active individual response to teacher interaction, passive individual response to teacher interaction, raising questions about visual contents, and participating the themed discussion of visual contents. Table 2 shows the results of the descriptive statistical analysis.

Table 3 shows the statistics on sample prediction results. It can be learned that the predicted realization degree of course goals of DAD teaching were close to the actual values. Hence, the application of VI technology to DAD teaching can ensure a high realization degree of course goals. The technology is feasible in that scenario.

Table 2. Descriptive statistics of students' VI behaviors

	N	Minimum	Maximum	Mean		Standard deviation	Variance
	Statistic	***Statistic***	***Statistic***	***Statistic***	***Statistic***	***Statistic***	***Statistic***
*VI*9	95	1	15	2.15	3.25	3.152	13.629
*VI*10	93	4	12	2.63	3.14	3.485	15.268
*VI*11	98	2	17	2.95	3.28	3.629	11.230
*VI*12	91	1	13	2.48	3.62	3.182	17.269
*VI*13	99	3	11	3.62	5.49	5.629	25.027
State list	96	1	15	0.01	0.03	0.07	0.03

Table 3. Statistics on sample prediction results

Group number	15	20	22
Actual value/%	25.1	13.8	7.4
Prediction value/%	21.9	15.2	4.2
Error	4.6	1.3	2.9

Figure 6 shows the ratio of teachers' interaction behaviors to students' interaction behaviors in a unit period. Figure 7 shows the ratio of male students' behaviors to female students' behaviors in a unit period. It can be seen that, during DAD teaching, the teachers' interaction behaviors were much more than the students' interaction behaviors. The students only had more VI behaviors in the latter half of the course, during the themed discussion period. As shown in Figure 7, male students had generally more VI behaviors than female students, and were more active in VI during DAD teaching.

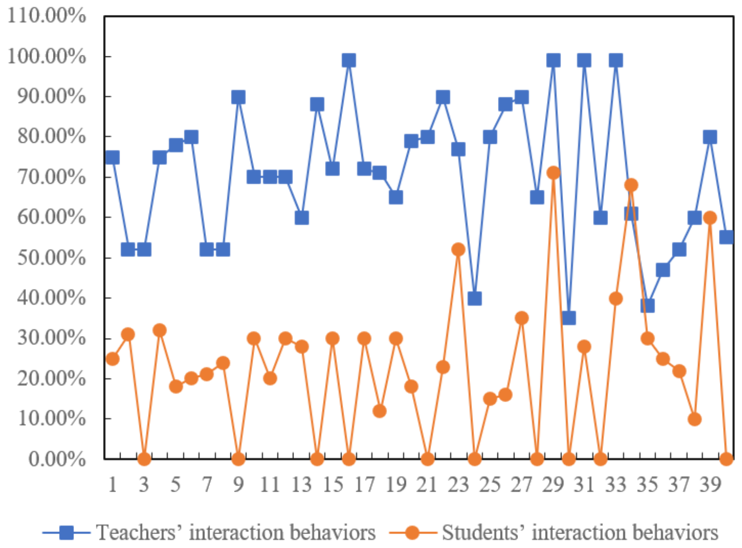

Fig. 6. Ratio of teachers' interaction behaviors to students' interaction behaviors

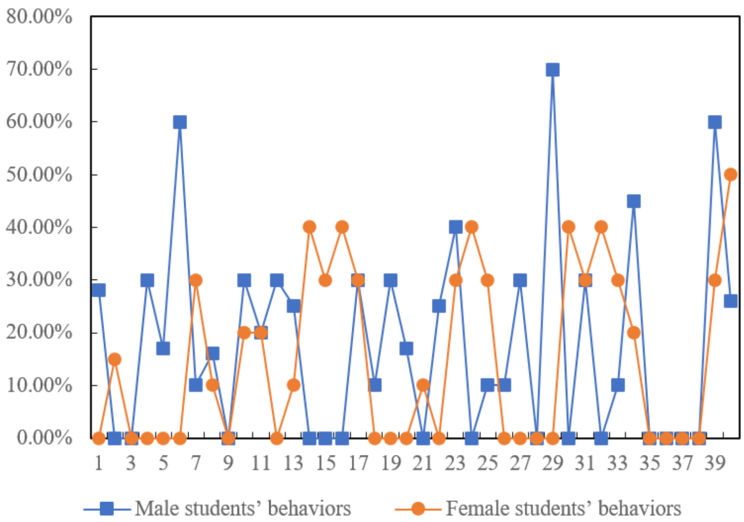

Fig. 7. Ratio of male students' behaviors to female students' behaviors

6 Conclusions

This paper explores the feasibility of VI mode in DAD teaching. After detailing the realization of teacher-student VI on DAD teaching process control platform, the authors set up the topology of VI system in DAD teaching. Then, the VI flow data were analyzed, and the teacher-student VI behaviors in DAD teaching were encoded. Afterwards, a prediction model was established for the realization degree of DAD teaching course goals based on the improved neural network. Through experiments, the visualization modes preferred by students were counted, and the necessity of VI technology application to DAD teaching was verified. Further, different descriptive statistics of VI behaviors were obtained, revealing that different subjects differ in the selection of VI behaviors in DAD teaching. In addition, the sample prediction results were summarized, indicating that the application of VI technology in DAD teaching ensures the high realization of course goals. Finally, the ratio of teachers' VI behaviors to students' VI behaviors, and that of male students' VI behaviors to female students' VI behaviors were plotted, and the relevant conclusions were drawn.

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