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Original Article

Exploration and practice of individualized medical teaching in advanced education based on learning analysis

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Abstract: Background: In accordance with the trend of international medical education development and to further promote the advancement of medical education in recent years, China's medical education objectives, policies and institutions undergone great changes. Since traditional teaching methods pay more attention to theoretical medical knowledge, the ability of medical students' spontaneous learning is relatively weakened. As a result, medical students need master more skills and ways of thinking. In order to meet the need of medical teaching, this study aims to explore a novel medical teaching and learning method by introducing a learning system. Methods: To provide a platform for individualized medical teaching and learning, this system was designed to restore the process of studying and analyze the behaviors, habits of studying. The evaluation was conducted on conceptual and methodical learning among 57 undergraduates from a medical university in Shanghai. And we obtained written informed consent from all participants. Learning attitude and attention degree, test results, learning habits and learning tracks of medical students were analyzed. Results: Data of the medical students were collected and analyzed in the field of study attitude, concentration degree, preference for study resources, study habits. The results can guide teachers to give medical students more pertinent learning advices and can analyze the efficacy of medical teaching. Conclusions: This learning system can help to guide teachers to give medical students more pertinent learning advices and can analyze the efficacy of medical students' spontaneous learning. Future studies are warranted to improve this system to establish prediction model of medical students' learning behavior and results.

Keywords: Individualized teaching, medical education, learning analysis, spontaneous learning

Introduction

Spoon-feeding teaching is still very common in many medical colleges in China because of limited number of teachers and teaching resources [1]. With the development of medical education, individualized teaching has been widely acknowledged and accepted. Individualized teaching emphasizes on the individual differences of students, respects to the personality of students and adheres to the policy that teaching should be performed according to students' needs. This concept, in fact, shares the same teaching conception of Confucius "Teach accordingly, teach individually". The fast development of Internet and multimedia technologies provide solutions for problems on individualized medical teaching. Various Internet-based education systems have been invented [2, 3], hoping to build a supporting platform on which medical students can choose their study contents and methods. These systems, to some extent, have realized individualized medical teaching; for example, medical students can choose different study contents according to their own needs, and select flexible study time and styles [4]. Many systems also had interactive platforms [5], which enable Q&A between teachers and students as well as students and students. Resources in some systems can be exchanged and shared, offering feedbacks of the study, such as the students' test performances [6]. However, the full practices of individualized medical teaching were hampered by

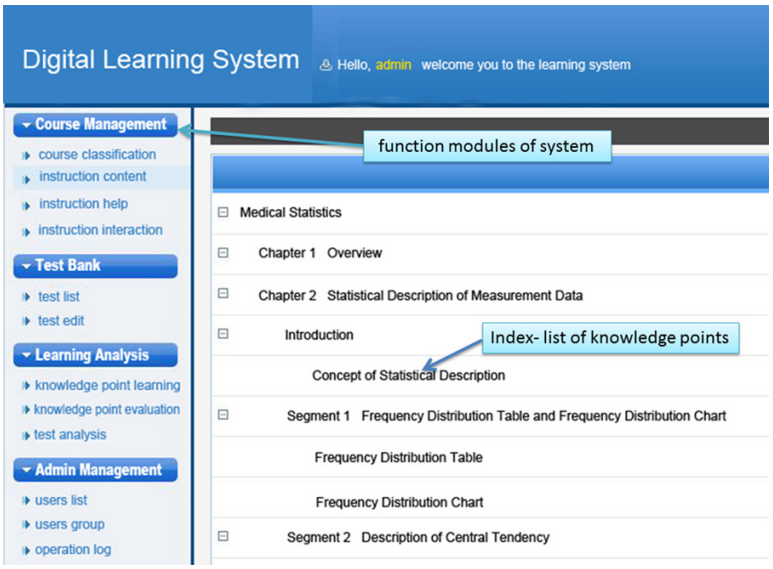

Figure 1. The basic interface of the system.

some shortcomings of these systems, such as (1) There is a shortage of teachers' real-time monitoring and managing during medical students' spontaneous learning, and the learning outcomes need to be evaluated and improved. (2) It is difficult for teachers to know and analyze the medical students' behaviors and habits during spontaneous learning, thus separating the medical teaching and spontaneous learning. Therefore, it is impossible for teachers to provide timely guidance and pertinent help to medical students. (3) Teachers have no access to the adaptability and applicability of medical educational resources, making it difficult to optimize medical educational resources.

To solve the problems above, this study aims to: (1) Setting up an education platform which can monitor and manage the process of medical students' spontaneous learning; (2) Collecting and recording the study data during the spontaneous learning, then analyzing the medical students' behaviors and habits, so as to provide evidence for teachers to make decision in individualized medical teaching [7-9], and (3) Considering the design and construction of medical educational resources.

Methods

Based on a previously education system developed by our team which can restore the process of students' spontaneous learning, we mainly focused on the system's revivification capacity of the process of medical students' spontaneous learning, and its supporting role in individualized medical education.

Functional analysis of our system

Each knowledge point was organized as a teaching unit in our system including all related medical educational resources, such as teaching video, slides show, electronic books, expanded resources and unit tests. Medical students can choose their learning contents and resources according to their needs for spontaneous learning after they entered into the system. Medical students could communicate and discuss with teachers and other students throughout the system in the process of learning. The basic interface is showed as **Figure 1** (translated from Chinese version).

To display the learning process and test results of the medical students, and allow the teachers to monitor and manage over the process of medical students' learning, we embedded an ANP (analytic network process) and content analysis into the system. These algorithms are used to collect and record all the data of the study process automatically. Based on the collected data, it would set up a current learning record of each medical student and analyze their attitudes, concentration degree, resources preference and learning habits. The ANP was mainly used to analyze the information distribution and the learning process in web-based learning [10-12]. Analysis of Log and Document was widely-used in Web Server to follow up and observe the users' visit rates, returning rates and online time. The learners' learning behaviors were judged through the number of the requests that users sent to web server, pointed constraints, the view of the web page. The time after a series of continuous requests to be idle for a period of time [13-15] was measured Content analysis firstly made labels with the text and multimedia information which had been used by the web-based learners; then it analyzed the labels to quantize and describe

Table 1. The index of learning attitude and attention degree

Item	Index
Learning attitude	Date and time of register
	Online time
	Average online time
Attention degree	Time stayed in each page
	Average learning time in each page
	Visit frequency of each page
	Average visit frequency of each page
	Frequency of teaching interaction

Table 2. Analysis of index of learning habits and learning tracks

Item	Index
Learning habits	Knowledge points
	Total learning time
	Time spent for watching teaching video
	Time spent for watching teaching slides
	Time spent for reading electronic material
	Time spent for learning extending resource
Leaning tracks	Sequence chosen of learning knowledge points
	Learning time spent on each knowledge point

the file information of the interaction between medical learners and educational resources objectively and systematically, and based on which it could catch the distribution condition of the resources which effectively supported medical learning.

Learning attitude and attention degree analysis

This system could assess the attitude and attention degrees of medical students by measuring online time, staying time on the page of each unit, visiting rates in every page and the frequency of reviews (**Table 1**). In addition to the above index, the system also offered the average level of all the index of the medical students in the same class, which could help medical students to compare with others and perform self-evaluation conveniently. The formulas of the index are listed as follows: Average online learning time was the sum of all the students' online time divided by the number of students; Average learning time in each page was the sum of learning time in each page of all the students divided by the number of students; Average visit frequency of each page was the sum of visit frequency in each page divided by the number of students.

The system calculated the degree of medical students' interests by analysing the average online learning time, average learning time on every page, sum of visit frequency of each page, and frequency of teaching interaction. Furthermore, the system evaluated the participation in learning of each medical student by comparing their index values with others', making it easy for the teachers to manage medical students' learning.

Test results analysis

We also designed a function of test analysis in this system to improve the efficiency of questions answering by teachers in class. Previous experiments showed that the medical students' questions from self-learning in the system were similar to those from traditional medical teaching. Therefore, the system not only offers the test grades, but also lists the wrong answers of each knowledge point according to the error frequency. With highest error rates the top three ones were to enable the teachers to know the understanding of knowledge points among medical students directly and the problems in their learning rapidly.

Learning habits and learning tracks analysis

The system can analyse medical students' learning habits and learning tracks by investigating their concentration level and learned content [16-18]. The main analysis indexes of learning habits and learning tracks are showed in **Table 2**.

The system showed the time used on each medical teaching resource such as teaching video, teaching slides, electronic material, extending resource for learning. All these data could demonstrate learning habits of students. The system displays the medical students' learning track by investigating the sequence of learning knowledge points and the learning time on each knowledge point. Then it can explore whether the learning track of a student accords with the relevancy among knowledge

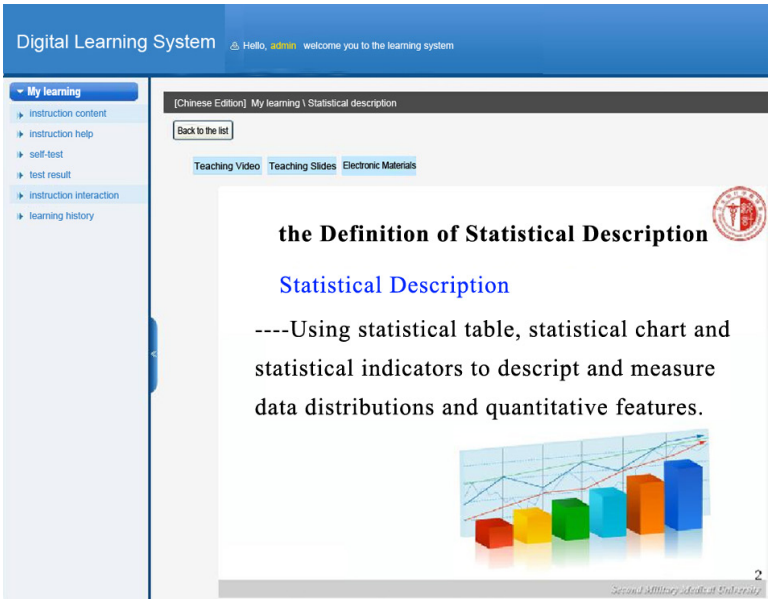

Figure 2. The teaching interface of the system.

points through comparing the sequences of learning knowledge points of different medical students. Analysis of learning tracks and learning habits can help to design curricular teaching and set up knowledge points.

The average learning time on each knowledge point can demonstrate the actual learning behaviour of medical students on each knowledge point. By observing the average time used in learning video, teaching slides, electronic material and extending resource, we knew how medical students distribute their study time on different educational resources in the same class, and the teachers can know about the learning habits of each medical student.

System evaluation

To evaluate the system's performance in analyzing the process of spontaneous learning, we take "medical statistics" as an example. It is a required course for all students in a medical college and is always considered one of the most difficult courses to learn in medical colleges. To evaluate the overall performance of this system, we carried out an educational experiment based on the features of the courses. Our investigation was divided into two parts: part 1 is for conceptual content, which has more statistical concepts and requires students to recognize and memorize, and part 2 is for methodical content, which has more methods and formulas and requires students to comprehend and apply.

According to the teaching standard of "Medical Statistics", chapter 2 is "Statistical Description of Measurement Data". It mainly introduces the common statistical tables and charts, as well as some statistics used to describe the features of measurement data. In chapter 2, "Frequency Distribution Table and Frequency Distribution Chart" and "Description of Central Tendency" were regarded as contents of part 1. The calculation of this part is easy and the content is weak in logic. Medical students need to pay more attention to recognition, remembering and distinguishing the different statistical features of measurement data and statistical symbols. Part 2 included "Chi-square Test of Two Independent Ratios" in chapter 8 "Chi-square Test" which mainly introduces the statistical idea and inference of chi-square test. Although the calculation of this part is easy, the content is one of the most important hypothesis tests with strict logic and has strong connection with the former knowledge points. Medical students need to comprehend the basic idea and logic of Chi-square Test, and to use this test to solve practical medical problems.

Study subjects

In part 1 of the experiment, 29 freshman volunteers whose major was clinical medicine were employed. All the participations in part 1 did not learn "Medical Statistics" previously.

In part 2 of the experiment, 28 sophomore volunteers whose major was also clinical medicine were employed. All the participations in this part had started learning "Medical Statistics" and mastered basic knowledge of hypothesis testing. And they were going to learn "Chi-square Test" in the next class.

Experiment process

First, participations logged into the system using their student number. Then they selected a content to start learning according to their learning habits. All the contents were listed in the "section" or "instruction help" module

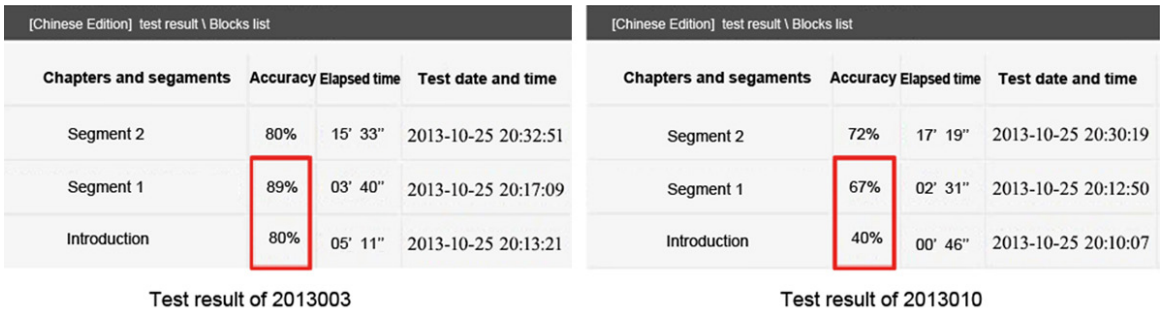

Figure 3. Comparison of test results between two medical students.

Table 3. The top three questions with higher error rates in the part 1 of the experiment

Knowledge point No.	Number of the question (error rate %)		
	Rank 1	Rank 2	Rank 3
1	Q5 (96.5)	Q2 (75.9)	Q1 (17.2)
2	Q7 (100.0)	Q3 (27.6)	-
3	Q5 (20.7)	Q4 (10.3)	Q8 (6.9)
4	Q32 (31.0)	Q2 (13.8)	Q1 (10.3)
5	Q33 (17.2)	Q5 (13.8)	Q6 (10.3)
6	Q13 (55.2)	Q37 (44.8)	Q17 (37.9)
7	Q19 (79.3)	Q18 (72.4)	Q20 (58.6)
8	Q30 (65.5)	Q43 (62.1)	Q27 (41.4)

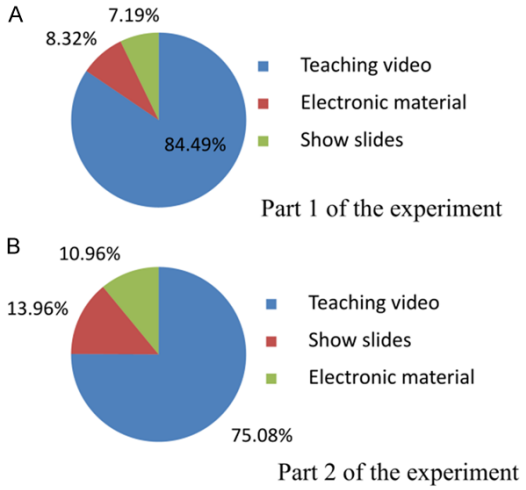

Figure 4. Allocation of watching time of different teaching resources.

which was in the navigation bar on the left of the teaching interface (**Figure 2**).

While entering the "section" module and choosing a content to learn, the medical students would see that the default is playing teaching video as start. They could control the video (go forward, draw back and pause, etc.) according to need. Medical students could also choose other teaching resources to start their study. After finishing all the knowledge points, medical students could complete the "self-test" module and submit his or her answer on line and receive their scores and correct answer automatically.

Results

Degree of students' attention concentration on learning

The system analyzed the degree of medical students' attention mainly on two aspects: test grades and learning track. The test grades which reflected the accuracy of the answer were the test scores of each knowledge point. The learning track was decided by time spent on each medical teaching resource. The test results of two students (number 2013003 and 2013010) for part 1 of the experiment are shown by **Figure 3**.

The test grade of student No. 2013003 was obviously better than that of student No. 2013010, especially in introduction and section 1. Comparing the corresponding knowledge points and the learning history of these two medical students, we found that the learning target of student No. 2013003 was clear and defined, and he spent quite a long and centralized time on various resources. While student No. 2013010 used a long time to repeat learning knowledge point which had been learned again and again in his learning history. We found that he viewed different knowledge points with very high frequency, but the actual time for each medical teaching resource was

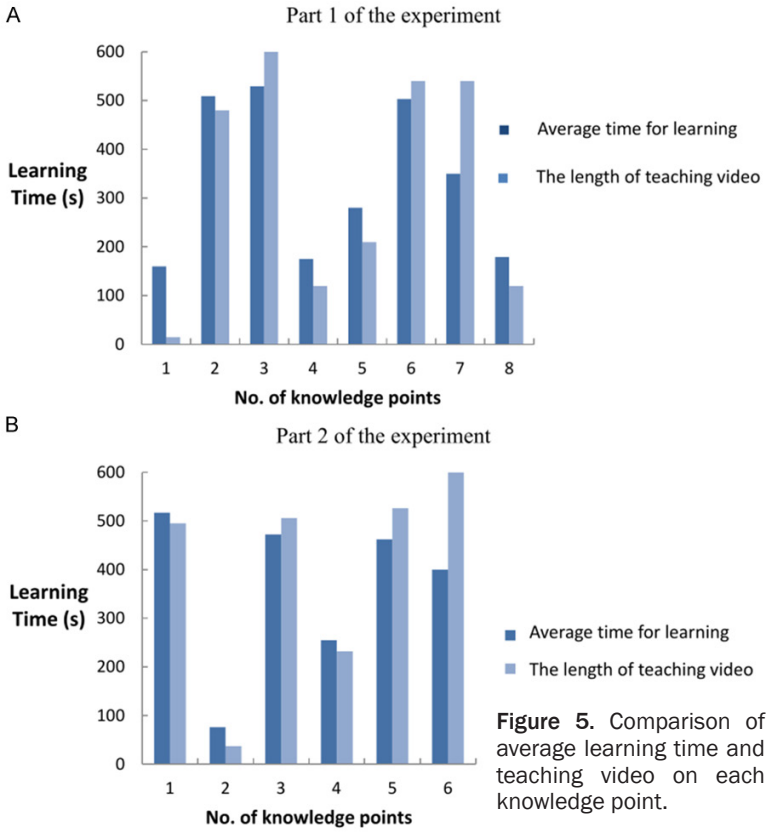

Figure 5. Comparison of average learning time and teaching video on each knowledge point.

very short, only one or two seconds, indicating that he did not concentrate on comprehending the knowledge points and he simply jumped from one knowledge point to another, which was not helpful for mastering knowledge.

Test results

Based on the answers, our system ranked the error rates of all the questions in each knowledge point from high to low and identified the three questions with the highest error rates. The results of part 1 which has totally 8 knowledge points is shown in **Table 3**. There were 9 questions in 5 knowledge points that had an error rate over 50%. The highest error rate was observed in question 7 in knowledge point 2 (100%). However, the error rates of questions in knowledge point 3, 4 and 5 were much lower, with all of the error rates below 35%.

Preference of learning resource

Medical students' preferences of different teaching resources may influence their comprehending and mastering of knowledge. Their preference can be reflected by allocation of the time that students spent on different medical teaching resources. The system can display the top three teaching resources of each knowledge point with most time spent: teaching video, teaching show slides, and electronic materials (**Figure 4**).

The results showed that the teaching video dominated the leading status. It is the main way for medical students to gain new knowledge and played a very important role in medical student spontaneous learning. For part 1 of the experiment mainly with conceptual content, watching video accounted for 84.49% in the total study time, indicating that medical students can better master the conceptual knowledge by watching videos. Nevertheless, the watching time of the videos in the experiment part 2 is lower relatively. This part is about methodical knowledge, which requires much more logic thinking and is difficult to learn. **Figure 5** illustrated that for the methodical knowledge, students need various teaching resources, and teaching video is also the main resource. To evaluate the application outcome of the system for different kinds of knowledge, we compared and analyzed the main results of two parts of the experiment. **Table 4** showed that medical students selected different teaching resources. For the conceptual content, medical students mainly select teaching videos. For the methodical knowledge, they learned through three teaching resources: videos, slides and electronic materials.

Considering the significant role of teaching videos in medical students' learning, it is very important to know the quality and actual efficiency. The system also offered further analysis on application of teaching videos. It compared the length of the teaching videos and the average learning time of each knowledge point (**Figure 5**).

Figure 5A shows that the teaching video of knowledge point 1 is only 15 seconds long,

Table 4. Comparison of students' selection of teaching resources for different types of knowledge

Types of knowledge	Teaching Videos (%)	Teaching Show Slides (%)	Electronic Materials (%)
Conceptual knowledge	82.76	6.90	10.34
Methodical knowledge	51.72	31.04	17.24

greatly shorter than others, and much shorter than the average learning time. We found that many medical students repeatedly watched this video. It is clear that the information offered by the teaching video of knowledge point 1 is too little. Medical students cannot master the key point by the video which is only 15 seconds, so we suggested the teachers to strengthen the explanation and illustration of this knowledge points. For the other 4 knowledge points, the average learning time was a bit longer than the length of videos, which was much more reasonable. But knowledge points 3, 6, and 7 showed a different feature: the lengths of these three videos are 10 min, 9 min and 9 min, respectively, being much longer than the others. We discovered that many students did not watch the whole video of these three knowledge points and some students only watched one third of the teaching video. But the average grade of knowledge point 3 is 91.38, indicating that most students had mastered this knowledge point very well. Therefore, the teacher is supposed to consider shortening the teaching videos of this knowledge point. For knowledge point 6 and 7, the average grade was only 71.04, meaning that medical students did not master this knowledge very well. The reason was that most of them have learned the knowledge in high school and the teacher should make an effort to draw the medical students' attention so as to make them finish the teaching video. The system also should design some prompting tips to inform students about the next teaching video. For example, knowledge point 7 was about "Median", the first half of the video was much easier, many medical students learned quickly and thought they have mastered, and neglected the new knowledge of "Notes of Median's Application" in the second half of the video.

Figure 5B shows that part 2 had the same result as part 1. If the teaching video was longer than the average learning time for a knowledge point, such as knowledge point 3, 5, 6, teacher should advise that the medical students may not watch the entire video. We also found that medical students who spent more time to learn show slides or electronic material rather than teaching video had a relatively poor test grades. To these knowledge points, teacher should simplify or optimize the teaching contents to guide the medical students to watch the whole video.

Learning habit

The analysis of the medical students' leaning habit was performed mainly by objectively observing the track of students learning in the system. For part 1 (conceptual content), learning habits were to learn the knowledge points one by one in the default order after logging in the system, and most medical students (82.8%) started their new knowledge by watching the teaching video. A majority of medical students (69.0%) learned by the order of video, show slides, electronic material and extending resources. We found that 25 medical students (86.2%) learned by the default order of knowledge points, only 4 medical students (about 13.8%) chose different knowledge points to start learning to their need.

For part 2 (methodical content), the medical students' learning habits was substantially different. After logging in the system, 20 medical students (71.4%) start spontaneous learning by the default order and never come back to the knowledge points they had learned. 28.6% of the medical students chose different knowledge points to learn according to their need rather than the default order. We also found that medical students had a common feature that they always repeated learning one or some knowledge points after they completed the study of all knowledge points. Moreover, about 50% of the medical students chose to start learning from watching the teaching video, and the other 50% chose show slides or electronic material.

Discussion

In this study, we validated that this learning system could effectively facilitate the learning process by recording the attention concentration, test results, usage of learning sources, learning

habits in both conceptual and methodical learning.

This system would benefit the teachers in following aspect. Firstly, this system can effectively record the attention concentration of specific individuals and thus provide information to whom the teacher should pay more attention. By analyzing the degree of concentration, teachers could identify students who easily change their learning targets more precisely. These medical students generally did not learn systematically, and their degree of learning concentration was lower than others with satisfactory learning outcomes. Therefore, teachers should pay special attention to them and give actively intervene while offering help and guidance for them to improve their study efficiency.

Secondly, every answer to the question was recorded which made it possible for the teachers to review and locate the difficult questions. Error rates of different questions may offer useful hint for the teachers. Teachers could know how medical students master the knowledge and give teaching direction conveniently. For instance, for questions with a quite low rate of error, less attention should be offered and for questions with a high error rate, extensive analysis of the reason of wrong answers should be performed with further notice of this knowledge point in reviews should be performed.

Thirdly, the teachers can effectively acknowledge the detailed learning habit of students. For instance, they can adjust the teaching sequence according to the most dominant habits, both in this system and in traditional classroom teaching. Also, they can adjust the proportion of each part of learning materials to meet the need of medical students. For instance, if the video is too long for the medical students to watch or it is too hard to comprehend, modifications should be made to cut the essence of the video or to extend the video by adding further explanation.

In addition, the preferred learning resources was recorded and analyzed. According to the results of this study, we encourage teachers to better combine this learning system with the classroom teaching: (1) The teaching videos play a vital role in student spontaneous learning and most medical students choose the teaching videos to start their learning. So we suggest that the teachers should make more efforts to optimize the teaching videos. For key knowledge points, teaching videos are supposed to be of a proper length. Teachers can use simple words and vivid frame to illustrate the knowledge much clear and interesting to attract the students, and they can also use some visualization technology to develop cartoons to help medical students. (2) For the conceptual content, teacher can give medical students enough time to the students for self-learning in the system, rather than classroom teaching. Teachers can know the understanding levels of medical students for each knowledge points by the system's real-time feedback. For personal learning problem, teacher can also teach in a one-to-one manner using the system. For common questions, teacher can answer them publicly in the system. Therefore, this system not only frees teachers from repeating the same content in different classes, but also has benefits in cultivating medical students' ability of spontaneous learning. (3) For the methodical content, medical students can spend some time to learn by themselves before classroom teaching, which can help teachers know medical students' learning problems directly in the system, and then they can design the key points in later classroom teaching and give clear illustrations in classroom. The teachers should provide reference materials as many as possible in the system, in addition to teaching video, show slides and electronic materials. Varied materials can help students understand knowledge more rapidly. The system can promote medical students' subjective initiative, allowing them to learn with questions, improving the outcome of classroom teaching.

Some confounding factors that might influence the accuracy and the representativeness of the learning data collected should be considered in the evaluation of our system. In our experiment we gave serious consideration to the selection of participants, which guaranteed a similar knowledge background and study level for the participants.

Our investigation also has some limitations. First we did not evaluate medical students' performance based on their spontaneous learning data collected in the system [19-21]. Second, the analysis of medical students' spontaneous learning is supposed to knowing the learning

habits and features of students, which can help us to offer some reference on individualized medical teaching and learning [22]. However, the more research needs to be performed. Third, we also hope to predict medical students' study outcomes by their learning behaviors, set up a corresponding prediction model, and realize the early warning of learning problems [10, 22].

In future studies, full use of the medical students' learning data accumulated in the system would be used to improve the function of this system. Establishing the prediction model of medical students' learning behavior and result, and the system can provide more evidences for medical education decision, and help teacher to design different learning plans and give different teaching supports for individual medical students.

This learning system can collect studying data of the students and analyze their study attitude, concentration degree, preference for study resources, and study habits of medical students. By doing this it can guide teachers to give medical students more pertinent learning advices and can analyze the efficacy of teaching. Future studies are warranted to improve this system to establishing prediction model of medical students' learning behavior and results.

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Disclosure of conflict of interest

None.

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