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Research on the small private online course (SPOC) teaching model incorporating the just-in-time teaching (JiTT) method based on mobile Internet for learning college physics

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Abstract

Based on mobile Internet and cognitive psychology, this study explores the effectiveness of the small private online course (SPOC) teaching model for the learning of college physics. The research involves designing and implementing the SPOC teaching model, which incorporates the 'just-in-time teaching' (JiTT) method, and collecting and analyzing relevant data. The statistical results show that there are significant differences in the exam mean scores and pass rates between the experimental group and the control group. They also show that students' learning effect is obviously correlative with their online learning behavior. There is no significant difference in learning effect between different genders in the experimental group. The tendency for student participation in the online learning is upward, and nearly 94% of the students like the teaching model.

Keywords: mobile Internet, SPOC teaching model, JiTT method

(Some figures may appear in colour only in the online journal)

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1. Introduction

Contemporary students belong to the Internet generation, and their norms are often inseparable from it [1]. They want to learn, but often do not like to spend much time reading textbooks [2, 3]. They also want to learn in a style that is best for them, and generally prefer reading web pages and content on the Internet to obtaining information from textbooks [4, 5]. They also have a need for efficiency: anything that reduces the time for their learning process becomes attractive and valuable [6]. Many previous studies have shown that web-based multimedia learning modules are more attractive to students and more efficient in terms of both study time and in-class activities, and thereby have a positive effect on student achievement [4, 6–9]. Furthermore, alongside the backdrop of the Internet, the massive open online course (MOOC) [10, 11] and the small private online course (SPOC) [12] models have emerged. Compared with a MOOC, a SPOC is a more suitable teaching method for students in college. The SPOC teaching model can enable individualized learning, flexible teaching, and face-to-face communication, as well as realize a human element and cultivate emotional values. It takes the advantages of a MOOC and is a blended teaching model which combines online teaching with offline physical teaching [13–15].

In addition, the core of the just-in-time teaching (JiTT) method is interaction and corrective feedback in real time [16–20], which enables teachers to know students' existing or prior knowledge and areas for improvement in their study, allowing teachers to adjust teaching content and strategies appropriately. So, teaching in this way can reduce students' frustration with their learning process, and improve their initiative, enthusiasm and learning effectiveness, which can furthermore stimulate curiosity and desire to learn. However, the JiTT method needs timely communication between teachers and students, something which was difficult before the Internet was available. But now, this technology, and particularly the mobile terminal Internet technology offered by smart phones and tablet computers, has provided favorable technical support for real-time interaction between people. How best to use mobile Internet technology to promote teaching reform, and how to use the potential of smart phones and tablets as students' learning tools, are questions for every educator.

Furthermore, research has found some gender gaps in different areas in STEM, such as exam scores and exam pass rates, attitudes and beliefs about learning, and even capability of learning. The situation differs between different countries and colleges [21]. Some studies have shown that male students perform better than female students in physics learning [22–24], but that is not absolute [25]. In our previous study, we found that women outperformed men in physics learning in some colleges and universities in China [26]. We want to discover whether the reformed introduction model described in this paper can reduce gender differences in physics learning.

This paper is based on mobile Internet and cognitive psychology theory, using smart phone or tablet computer mobile terminals to realize timely interaction between instructors and students, as well as among students. We adopt appropriately designed multimedia learning materials based on the mobile Internet, and implement the SPOC teaching model which incorporates the JiTT method. Some relevant data are collected and quantitatively analyzed to explore the effectiveness of the SPOC teaching model combined with JiTT, through comparison with a traditional teaching model for college physics. The main purpose of this paper is to find the following: (1) the difference in exam mean scores and exam pass rate for students experiencing different teaching models; (2) the correlation between students' online learning behavior and learning effect; (3) the influence of gender on students' learning effect.

In section 2, we describe the theoretical frameworks for our research and the potential of the reformed teaching model in this project. In section 3, we introduce the design of the research and the execution of the project. In section 4, we analyze the data in detail and draw some important conclusions. In section 5, we discuss the main findings and the limitations of the reformed teaching model, and give a summary of the study.

2. Theoretical frameworks and SPOC teaching model

2.1. Theoretical frameworks

The work of this paper is based on three theoretical frameworks of cognitive psychology: constructivism theory [27], cognitive load theory (CLT) [28–31], and the cognitive theory of multimedia learning (CTML) [32, 33].

First, constructivism theory emphasizes that students are the main body of learning, holding that everyone's understanding of the world is based on a hereditary schema. Learners must actively and profoundly process novel information in order to contextually integrate it with their prior knowledge to enrich their schemas and change their schemas qualitatively.

Second, CLT tells us that human cognitive architecture is characterized by a very limited working memory (WM) and a very large long-term memory (LTM). There are three kinds of cognitive load: intrinsic, extraneous and germane. During learning and teaching, the total cognitive load cannot exceed the capacity of the WM, otherwise the presented information will not be correctly processed, and the process will not correctly engage in schema acquisition.

Third, the CTML provides good ideas on how to design course materials to reduce cognitive load. Humans have separate audio and visual channels to process information, and each has a limited capacity. Meaningful learning occurs when learning materials are presented in a multimedia format, in which a learner selects relevant information (words and images), organizes these into each channel, and finally integrates the selected information with prior knowledge into a coherent representation in the LTM. Hence, course materials should be designed in multimedia form, enabling students to be engaged in multimedia learning, fostering learning and improving problem solving.

In addition, research has proved that timely feedback through discussion with peers or instructors can impact students' self-efficacy and self-evaluation, which have a positive impact on students' learning effect [34, 35].

2.2. SPOC teaching model

The SPOC teaching model incorporating the JiTT method used in this paper is based on the environment of the mobile Internet, and a mobile course platform including multimedia learning materials built by ourselves. It is a combination of online learning and conventional face-to-face teaching. In the teaching model, students use mobile terminals to preview and review the learning materials which have been posted on the platform in advance. Students first teach themselves online, ahead of class, and then attend the regular class to participate in offline study. Throughout the teaching and learning process, teachers and students can interact in real time on the mobile course platform via the mobile Internet. In this way, different students can arrange their learning progress according to their abilities, schedules, and study habits. Teachers have the responsibility of teaching students how to learn and how to construct knowledge. Students are the main body, and teachers have the leading role in the process of the learning and teaching activities.

Furthermore, because of students' online learning and the timely interaction on the platform between students and teachers, instructors can understand students' relevant prior knowledge well, enabling the regular classroom teaching to be more targeted, informative and innovative than in a traditional teaching model. Teaching in this way can keep the intrinsic cognitive load at an appropriate level to ensure that it does not exceed students' WM capacity.

Moreover, this kind of teaching activity moves from online to offline. By using this model, we enable the traditional classroom to add an online autonomous preview, review, and real-time interaction (to realize corrective feedback) between teaching and learning, which is very helpful, and with the help of the mobile Internet, not difficult or time consuming. For students who have difficulties or make slower progress in learning, the model allows for a time difference that can compensate and help them assimilate knowledge. The model may therefore minimize students' frustration, and improve their learning enthusiasm, self-efficacy and self-evaluation. Their germane cognitive load may therefore be automatically increased, due to feeling positively towards devoting their efforts to learning.

In addition, the learning materials, whether posted on the mobile course platform or presented in the classroom, are all in a multimedia form. According to the CTML, this is a good way to reduce students' extraneous cognitive load while learning.

To summarise, through online preview, review, just-in-time interaction, feedback, and offline traditional teaching and learning, the schema structure of students may be correctly changed step by step and the purpose of teaching is successfully attained.

3. Description of the study

3.1. Tools and construction

At present, almost every college student has a smart phone, which is the favorable and necessary condition for the successful implementation of this project. There are two kinds of tools to be used in the study: the mobile course platform for the college physics content and a smart phone or tablet that can be connected to the Internet. The construction of the mobile course platform includes the creation of 104 micro-course online videos, collecting animated multimedia illustrations, and compiling exercises, classroom quiz questions, homework and other online course materials, which cover all the knowledge points of the college physics curriculum and serve as the curriculum materials for students to learn online. This construction process lasted for over a year. With the help of the mobile Internet and mobile course platform, teachers and students can communicate anytime and anywhere, and teachers can track, detect and evaluate students' learning process. Through the students' learning data, teachers can also become aware of their learning state, so as to adjust the teaching progress and focus, and, as mentioned, look to make the face-to-face offline classroom teaching more targeted.

3.2. Implementation process

The main purpose of the study is to explore the effectiveness of the SPOC teaching model incorporating JiTT, as well as to look for an effective teaching method supported by the mobile Internet.

First, we tried to combine Internet tools with traditional teaching. We set up the mobile course platform for the college physics content, which was compatible with PC and mobile terminals, and tried it out in actual teaching activities. After accumulating some relevant teaching experience, we implemented the SPOC teaching model with the JiTT method in a real college physics course, teaching it for four semesters.

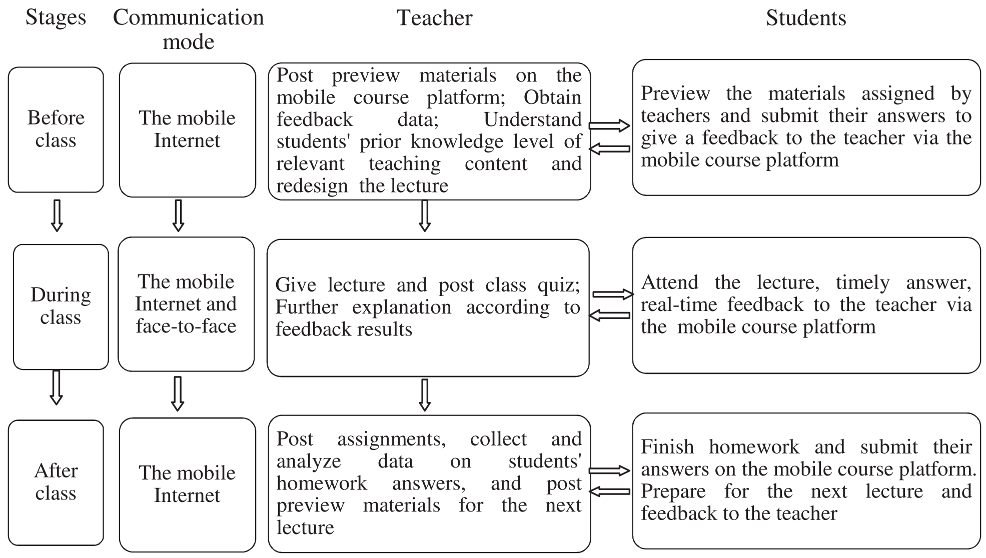

Figure 1. Teaching model of SPOC incorporating JiTT.

The students involved in this project were all majoring in engineering, and their college physics course lasted two semesters. For the sake of easy distinction, we usually call the course ‘College Physics 1’ and ‘College Physics 2’, which are always offered in the spring and fall term, respectively. The subjects were 816 students who were randomly assigned into two groups, with 446 in the control group and 370 in the experimental group. The control group learned through the traditional teaching model, that is, face-to-face teaching, post-class review, homework and so on. With the help of mobile Internet, smart phones and the mobile course platform, the experimental group’s teaching process was divided into three main stages (as shown in figure 1):

(i) Before class, teachers post materials on the mobile course platform and ask students to preview and reply within 24 h. Teachers then redesign the lecture based on the students’ feedback.
(ii) During class, teachers give the lecture, answer any questions submitted by students before the class, and post a quiz to check the effectiveness of the classroom teaching. Students answer and give feedback to teachers in a timely manner, and teachers provide further explanations according to the students’ replies. This process takes about 10 min, depending on the degree of students’ understanding of the new knowledge which has just been taught in the lecture.
(iii) After class, teachers post assignments and require students to review what have been taught in class, to finish homework and to submit their answers the morning of the day before the next lecture, and then repeat the first step.

With the help of mobile Internet, teachers and students can interact in real time on the mobile course platform by using smart phones or tablets. The classroom teaching activities can be carried out in accordance with the students’ cognitive state. Teachers design teaching content and exercises related to the course and post them to the students’ mobile terminals in advance via the mobile course platform. Through the platform, teachers can check the students’ preview situations by using a PC or smart phone. Based on these data, the emphasis of

Table 1. Statistical description of the exam scores of students taught by different teachers.

Groups	Instructors	N	Mean	Std. deviation	Std. error
1	A	197	61.8	17.2	1.23
2	B	227	60.8	16.1	1.07
3	C	199	59.9	17.3	1.22
Total	3	623	61.0	16.9	0.68

the classroom teaching and teaching progress is redesigned. After class, teachers continue to post related exercises, homework and quiz questions to the platform, and students respond, submitting their answers to the platform through the Internet. Teachers therefore understand in a timely manner the effectiveness of students' learning, and are able to make decisions about the content of the next teaching session, the progress of students, the degree of difficulty, and so on. The whole linked process realizes real-time interaction between teachers and students on the platform with the help of the mobile Internet.

Three instructors are involved in this project. In order to analyze the influence of different instructors on students' learning effect, we collected the data of the final exam scores from 623 previous students whose college physics courses were taught by the three instructors, marked as 'A', 'B' and 'C'. Table 1 is the statistical description of the exam scores of students taught by the three different instructors. The statistical results show that the mean scores of the three groups are slightly different, but the one-way ANOVA shows that $F = 0.859$ and the significance $p = 0.424 > 0.05$, which means that there is no significant difference in mean scores between the three groups. Therefore, we can regard the teaching abilities of the three instructors involved in this study as the same, and in the later data analysis, the learning effect of the experimental group and the control group is unrelated to the factor of the different instructors. Instructor B, who is much more familiar with the mobile course platform and has experience in JITT teaching, was assigned to teach the physics course for the experimental group, and the other two instructors (A and C) were assigned to the control group.

The curriculum requirements were identical for the experimental and control groups. They received the same textbooks, assignments, exercise questions, and teaching hours. At the end of each semester, they were given the same final exams at the same time, and the exam papers were exactly identical with a full score of 100 points. Only when a student's final exam score was more than or equal to 60 points were they recognized as passing the exam. During the implementation of the project, we collected the following data: gender, final exam score, whether or not they participated in online learning, online learning time and proportion of completed online materials. Finally, we administrated a questionnaire among the students in the experimental group to collect data concerning attitudes to the reformed teaching model.

4. Analysis and results

In the following statistical analysis, the significance level is 0.05 or 0.01; the latter will be specially marked.

Table 2. Statistical description of the final exam scores of experimental and control groups.

Groups	N	Mean	Std. deviation	Std. error
Exp.	370	64.0	15.5	.806
Con.	446	59.0	17.6	.832
Total	816	61.3	16.8	.590

Table 3. T-test for the exam mean scores of the experimental and control group.

Variances assumed	Levene's test for equality of variances		t-test for equality of means				
	F	Sig.	t	df	Sig. (2tailed)	Mean difference	Std. error difference
Equal variances not assumed	5.222	.023	4.357	810.8	<.001	5.047	1.158

4.1. Analysis for exam mean score difference

Table 2 is the statistical description of the final exam scores for this study, which shows that the mean scores of the experimental group and control group are 64.0 and 59.0 respectively, and the difference is 5.0 points. Table 3 is the results of the t-test, to see if the difference is statistically significant. According to the t-test, $F = 5.222$, $p = 0.023 < 0.05$, so not-equal variances should be accepted. Under this condition, $t = 4.357$ and the significance $p < 0.001$; thus, we can safely conclude that the difference in mean score between the two groups is statistically significant, and favors the experimental group.

4.2. Chi-square test for exam pass rate

The final exam pass rates of the experimental group and control group are 63.5% and 55.4% respectively (see figure 2). A chi-square test is performed to determine if there is a significant difference in the exam pass rates of the two groups. The results show that, $\chi^2 = 5.532$ and $p = 0.022 < 0.05$, so the difference in exam pass rate between the two groups is statistically significant. Thus, the pass rate of the experimental group is higher than that of the control group. The pass rate of the experimental group is 1.15 times of that of the control group.

4.3. Correlation analysis

In order to find the correlative relationship between students' online learning behavior and learning effect, we analyze the correlation between the students' exam scores, pass rate and the following three factors: whether they participated in online learning, the online learning time and the proportion of completed online materials (see table 4). The statistical results show that the correlation coefficients between exam scores and the three factors mentioned above are 0.481, 0.458, 0.411, and the correlation coefficients between the pass rate and the three factors are 0.403, 0.344, 0.249, respectively. All have a corresponding significance $p < 0.001$. Therefore, the correlation between students' learning effect and online learning behavior is statistically significant, and there is a positive correlation between the two. By

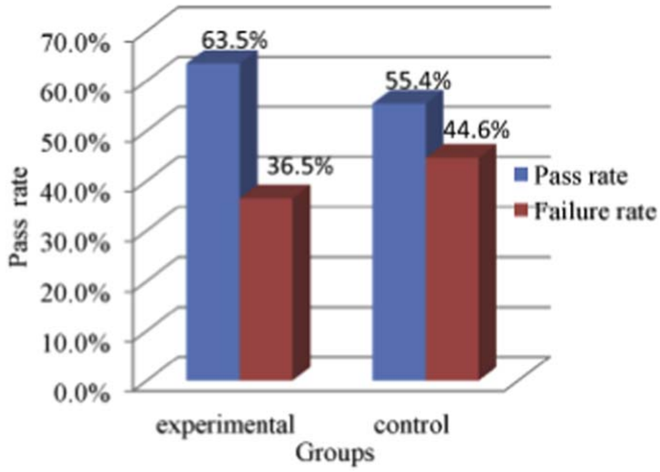

Figure 2. Pass rates of different teaching models.

comparing the correlation coefficients, we can see that the effect of online learning behavior on exam scores is greater than on the pass rate. Among the three factors, the online learning time is most relevant to the exam scores as well as the exam pass rate, and the correlation between pass rate and participation in online learning is the smallest, with a Pearson correlation coefficient $r = 0.249$.

4.4. Analysis of the influence of gender on students' learning effect

Studies have found that gender affects students' learning attitudes and their learning of content in a college physics course taught with a traditional teaching model. For some colleges in China, the learning attitudes of female students is better than that of male students, and female exam mean scores are often higher than those of males [26]. To see if the SPOC teaching model with the JITT method has a gender effect, we analyze the exam mean scores, pass rate, proportion of completed online learning materials and online learning time across the students in the experimental and control groups. Table 5 is the statistical description of the relevant data, and table 6 is the t-test results of the difference in the mean values of different genders. The statistical results are as follows.

For the experimental group, the exam mean scores, pass rates, the proportion of completed online learning materials and online learning time of different genders are slightly different (see table 5). According to table 6, the p values of Levene's test for equality variances are all greater than 0.05, so the variances are equal. The significance p values of the t-test are 0.594, 0.719, and 0.171, respectively, which are all much greater than the significant level 0.05. Thus, the differences in the mean values of the exam scores, proportion of completed online learning materials and online learning time among the students of different genders are not statistically significant.

However, for the control group, the mean scores of male and female students are 62.3 and 55.2 respectively, with a difference of 7.1 points (see table 5). According to table 6, $F = 18.210$, $p < 0.01$, so we accept that not equal variances are assumed. In addition, $t = 4.656$, $p < 0.01$, thus the difference in the exam scores of male and female students is statistically significant. This conclusion is the same as [26].

Table 4. Correlation analysis between learning effect and online learning behaviors.

Learning effect	Pearson correlation	Online learning time	Proportion of completed online materials	Participation in online learning
Mean score	Correlation coefficients	.481[a]	.458[a]	.411[a]
	Sig. (2-tailed)	$<.001$	$<.001$	$<.001$
Pass rate	Correlation coefficients	.403[a]	.344[a]	.249[a]
	Sig. (2-tailed)	$<.001$	$<.001$	$<.001$

[a] Correlation is significant at the 0.01 level (2-tailed).

Table 5. Statistical description for different genders of two groups.

Statistical items	Groups	Gender	N	Mean	Std. deviation	Std. error
Exam scores	Exp.	Male	206	63.6	14.89	1.038
		Female	164	63.5	16.27	1.271
	Con.	Male	217	55.2	18.58	1.261
		Female	227	62.3	14.42	.957
Pass rates	Exp.	Male	206	62.1%		
		Female	164	65.2%		
	Con.	Male	217	46.5%		
		Female	227	64.3%		
Proportion of completed online materials	Exp.	Male	206	13.89%	14.56%	1.01%
		Female	164	13.37%	12.66%	.99%
Online learning time (minutes)	Exp.	Male	206	340.3	299.9	20.90
		Female	164	385.2	327.2	25.57

The chi-square test for the exam pass rate of students with different genders in the experimental and control groups is performed. For the control group, $\chi^2 = 34.46$, $p < 0.001$, so the difference in the pass rate has a statistical significance, which is also consistent with our previous findings [26]. But for the experimental group, $\chi^2 = 0.381$, $p = 0.587 > 0.05$; although the pass rates of male and female students (62.1% and 65.2%, respectively) do differ somewhat, the difference is not statistically significant.

4.5. Analysis of students' degree of participation

In order to judge the degree of participation in the reformed teaching model implemented in the experimental group, we analyzed the changes in students' online learning time and the proportion of completed online learning materials over the spring and fall terms (see table 7). The results of the statistics in table 7 show that the online learning time and the proportion of completed online learning materials for students in the fall term are greater than those in the spring term. According to the results of the t-test (see table 8), the corresponding t values of these two variables are 5.338 and 14.575, respectively, and the significance p values are both far less than the significance level 0.01. This shows that the participation of students in the reformed teaching model increases, meaning that the reformed teaching model is popular with students.

To further determine whether the students feel positively towards the reformed teaching model, we administrated a questionnaire survey among the students in the experimental group in two semesters, and obtained 356 valid questionnaires. The statistical results shown in figure 3 show that 93.8% of the students liked the teaching model, while 6.2% did not. There are several reasons for students not liking the SPOC instruction model for learning physics. First, the Internet signal is not good in some classrooms, which hampers timely interaction between teachers and students. Second, when submitting answers to assignments or quizzes via the Internet, inputting mathematical symbols is slightly cumbersome. Third, if mobile terminals occasionally do not have electricity or no mobile terminal is at hand, it is impossible to complete the online study or timely feedback to the teacher. However, with the popularization of the Internet environment, the continuous improvement of mobile course platform

Table 6. T-test results of the difference in the mean values of different genders.

Statistical items	Groups	Variances assumed	Levene's test for equality of variances		t-test for equality of means				
			F	Sig.	t	df	Sig. (2tailed)	Mean difference	Std. error difference
Exam score	Exp.	Equal variances assumed	.806	.370	.534	368	.594	.868	1.624
	Con.	Equal variances not assumed	18.210	<.001	4.656	407.2	<.001	7.37	1.573
Proportion of completed online materials	Exp.	Equal variances assumed	2.280	.132	.360	368	.719	.518%	1.44%
Online learning time (minutes)	Exp.	Equal variances assumed	1.404	.237	1.372	368	.171	44.9	32.7

Table 7. Statistical description of participation.

Items	School term	N	Mean
Online learning time (minutes)	Spring term	183	275.8
	Fall term	187	442.8
Proportion of completed online materials	Spring term	183	5.32%
	Fall term	187	21.82%

software, and the increasing awareness of using smart phones as a learning tool, all these problems currently faced by students will be solved in the near future.

5. Summary and limitations

Based on the mobile Internet, this study executed a SPOC teaching model combined with the JiTT method, with the help of three kinds of combinations. The first is the combination of software and hardware. The software here refers to the mobile course platform including multimedia learning materials, and the hardware refers to mobile terminals, such as smart phones or tablet computers. The second is the combination of 'virtual' and 'real'. The 'virtual' is the online teaching or learning in a virtual environment and the 'real' is the traditional face-to-face teaching in real classrooms. The third is the combination of the two teaching methods, that is, the SPOC teaching method and JiTT method.

We explored these methods in the college physics course for four semesters, and collected data and completed a multi-dimensional quantitative analysis of student learning effectiveness. The results show that the exam mean score and pass rate of the experimental group are higher than those of the control group. Moreover, these two variables are positively correlated with the factors of online learning time, proportion of completed online learning materials and participation in the experimental group's activities. Students of different genders in the experimental group displayed the same learning effectiveness, which differs from that of the control group. According to the changes in online learning time and proportion of completed online materials in the spring and fall terms, it can be seen that the trend of student participation in the reformed teaching model is obviously increased; the results of the questionnaire survey further show that the reformed teaching model is very popular with students. The main reasons for this are that this teaching model is student-oriented, and the online learning is not subject to time and space constraints. Students are able to schedule their own learning progress according to their own learning conditions. If they encounter any learning difficulties, they can, in a timely manner, obtain help offered by other students or teachers, or the video materials on the platform via mobile Internet, which reduces their frustration with the learning process and enhances their interest in learning.

In addition, just-in-time interaction can make teachers aware of the degree of students' understanding in real time, enabling teaching activities to be carried out in a targeted way, which may in turn lighten students' cognitive load, make the process of knowledge transfer operate more smoothly, and certainly improve learning efficiency. However, in the real-time interaction between teachers and students, the Internet signal must be of high quality to support the ability of students to learn independently by means of the Internet, and mobile tools must be improved.

In summary, our data indicate that the SPOC teaching model, which incorporates the JiTT method via mobile Internet, is effective and feasible. It is superior to the traditional teaching model in terms of students' exam mean scores and exam pass rates. This research

Table 8. T-test of student participation change.

	Variances assumed	Levene's test for equality of variances		t-test for equality of means				
		F	Sig.	*t*	df	Sig. (2tailed)	Mean difference	Std. error difference
Online learning time (minutes)	Equal variances not assumed	20.915	<.001	5.338	339.57	<.001	167.0	31.28
Proportion of completed online materials	Equal variances not assumed	213.510	<.001	14.575	212.56	<.001	16.50%	1.132%

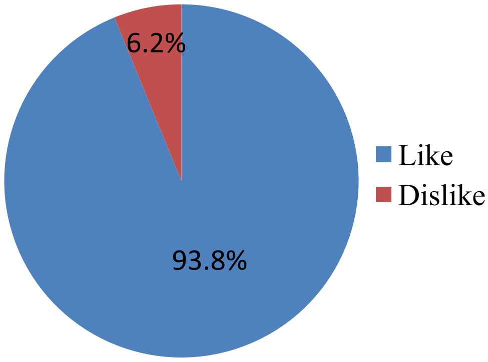

Figure 3. Questionnaire survey results of the SPOC teaching model.

provides a valuable reference point to continuously promote education reform and innovation, and to help transform and upgrade the teaching model.

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