Analysis of the Effects of the "Pedagogy - Space - Technology" Framework on University Student's Learning Efficiency

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Abstract—In the background of the global COVID-19 pandemic, the popularization of intelligent online teaching platforms dominated by advanced teaching technologies is accelerated. The 'Pedagogy-Space-Technology' (PST) framework learning space provides students high-quality teaching resources. The overall learning efficiency of students is dissatisfying because students lack intrinsic motivation to learn. Based on existing "intelligent teaching platforms of the PST framework" and combining with the principle of improving internal drive force of students through external guiding strategies, an experiment was designed in this study. The course *Technical Analysis of the Financial Markets* launched as an open online optional course for Chinese six undergraduate universities in 2021 and was chosen as the research example. Experimental data in 16 weeks were collected to analyze the effects of the PST framework learning space on overall intrinsic learning ability, staged academic performances, and online learning behaviors and improvement degree of intrinsic independent learning ability of students. The students' independent learning ability is generally improved, but their attitude improvement is not obvious. The academic performances of students are generally improved, especially for students with low intrinsic independent learning ability. The online learning behaviors of students with low intrinsic independent learning ability are not dissatisfying, but their independent learning ability is improved significantly. In this study, the relationship between the PST framework learning space and learning efficiency of students was disclosed from the perspective of the internal-driving and external-guiding teaching model. The obtained conclusion provides a way for university teachers to provide students with emotional support, design multiple teaching technological activity combined strategies, offer external guidance with timely and high-efficiency feedbacks, and improve learning efficiency.

Keywords—internal-driving and external-guiding teaching model, PST framework learning space, empirical analysis, learning efficiency

1 Introduction

Promoting effective learning has been a core problem that is highly concerning in the education field. The constructivism believes that teachers shall be assistors of

construction meaning of students and they shall stimulate learning interests of students and help students to form learning motivations. With the development of learning scientific and technological applications, applications of intelligent technologies such as data mining, learning analysis, and resource recommendation to the education field even promote development of external learning guiding strategies, while "external guiding" becomes an important means of realizing "internal drive". "External guiding" refers to guidance and promotion of process by external strategies or measures. "Internal drive", or intrinsic driving, refers to stimulation and training of internal motivations [1]. Internal drive is often equivalent to motivation. External incentives are closely related with the internal drive and influence behavioral performance of individuals. In real classes, many "external guiding" strategies are stimulating learning motivations and interests of students continuously. For example, introduction activities in class, cooperative activities in class and teacher-student or student-student interactions all promote changes in students from "passive learning" ("external guiding") to "positive learning" ("internal drive").

In the network environment, the online learning conditions are complicated and are changing due to multiple learning groups, rich learning resources, free learning modes and open learning space. Without a high metacognitive capability or independent learning ability, online students may have difficulty sticking to learning continuously, unless there are external guiding measures [2]. Moreover, Internet upgrading and development also brought some changes in the creation mode of knowledge. Active participation and cooperative construction became important ways of knowledge acquisition [3]. Cooperation and construction through social interaction during the online learning process may not only stimulate intrinsic motivations, such as interest, thinking, and desire, but may also generate new learning motivations, such as group impetus [4].

The pedagogy-space technology (PST) framework is proposed by Professor D. Radcliffe from the Queensland University in 2009 based on the next-generation learning space (NGLS) project [5]. PST contains three elements of "pedagogy, space, and technology". Specifically, pedagogy provides action guidelines for combination of technology and learning space. Learning space promotes pedagogy and embeds information technologies into it. Information technology strengthens the effect of pedagogy and expands the scope of learning space in return. Thus, pedagogy, learning space, and technology complement one another. **How can one design "external guiding" strategies to stimulate the intrinsic learning drive during online learning in PST framework learning space?**

To improve the teaching management for PST framework learning space and particularly to overcome teaching difficulties in massive online public optional courses for undergraduates in the university, the effects of internal-driving and external-guiding learning mode were observed in this study through the online course of *Technical Analysis of the Financial Markets* on the "Chaoxing Fanya" platform with the PST framework learning space. Influences of internal-driving and external-guiding teaching mode of the PST framework learning space on independent learning ability, online learning behaviors, and academic performance were analyzed and investigated.

2 State of the art

In the background of popularizing the PST framework learning space, learning efficiency varies among students who are in various learning environments. Any learning activity of human is influenced by internal and external motivations. Internal motivation refers to a type of intrinsic desire of individuals for learning [6-7]. In 1968, Ausubel [8] summarized three internal drives from the perspective of achievement motivations and applied them in teaching activities extensively, which were cognitive drive, self-development drive, and affiliated drive. Cognitive drive is a need of knowledge seeking. It has to stimulate interest, use the curiosity of students and establish problem situations cleverly to trigger the cognitive drive. Self-development drive is a type of need that viewing academic achievements as gaining corresponding social status and it may be a need of self-identity construction for online learning. Affiliated drive is a type of need of efforts in academic studies to win the peers and authority figures' approval. Clark Hull [9], a psychologist, once described that internal drive exists inside bodies and it is triggered by external factors, and these internal drive and external incentives interact to produce behaviors. Incentives refer to objects, situations or activities that can fulfill the students' needs. This further disclosed the internal relationship between external guiding measures of incentives and internal drive [10].

According to the relation principle between external guiding and internal drive, Qin Yu [11] proposed the concept of instructor-led online learning for the first time in 2005. Scholars began to pay attention to theoretical innovation, mode construction, and practice exploration of instructor-led online learning. These instructor-led online learning activities are practices of external guiding strategies and they further elaborated on the importance of external guiding on online learning [12]. High and new technologies in existing intelligent teaching platforms can help construct new learning modes and form internal learning drive [13]. This is essentially a technology-enhanced learning environment and seamless cooperative learning and individualized learning can be realized in such a learning space [14-15]. An intelligent learning space can be formed by integrating cloud services, teaching, and resource platforms [16]. Supported by appropriate technologies, tools, resources, and activities, various behavioral data in the learning process can be recorded and analyzed, thus providing students with individual learning tasks and activities according to their needs [17]. This is conducive to realize the goal of motivating internal-driving self-learning effectively [18-19]. The internal-drive learning functions in the PST framework learning space include supporting self-paced learning of students, perceiving the learning state of students, providing timely visual learning feedbacks, and helping students make learning plans, monitoring learning activities, evaluate learning outcomes, reflect and adjust learning behaviors [20]. Such a learning mode is conducive to promote deep learning and improve their self-learning efficiency and independent learning behaviors [21].

However, what is the influence of such internal-driving and external-guiding learning mode of PST framework learning space on the learning efficiency of students? In the PST framework learning space, specific evaluations lack quantitative evidence

support and have strong subjectivity due to the high number of learners and limitations by small-sized classroom and time. It cannot provide references in designing accurate external guiding strategies to improve the students' internal drive in the follow-up online courses.

In this study, an experiment was designed based on the "internal drive theory and instructor-led teaching principle". How learning ability, academic performances and online learning behaviors of students influence mutually and what are their relationship during "internal-driving and external-guiding" teaching were investigated deeply using the "reliability theory and paired-sample T-test" method. This study tried to collect and analyze data about intrinsic independent learning ability, academic performances and online learning behaviors of students. The following problems that students encounter during internal-driving and external-guiding teaching mode in the PST framework learning space were discussed. What is the influence of "internal-driving and external-guiding" teaching mode on the general independent learning ability of students? What is the influence of "internal-driving and external-guiding" teaching mode on staged academic performance, the original independent learning ability and general academic performance? What is the influence of "internal-driving and external-guiding" teaching mode on online learning behaviors and improvement degree of independent learning ability? This study aims to provide references to design accurate external guiding strategies for the follow-up PST framework learning space.

3 Construction of PST framework learning space supporting the "internal-driving and external-guiding" teaching mode

3.1 "Chaoxing Fanya" platform supports the "internal-driving and external-guiding" teaching

In the "Chaoxing Fanya" platform with the PST framework learning space, various subsystems of teaching management, teaching organization, and teaching evaluation were highly integrated. Generally, the teaching space was designed by observing the principle of pedagogics-space-technology (PST) [22]. "Chaoxing Fanya" platform integrated the "Xuexitong APP". By using new technologies such as mobile internet, cloud computing and big data, wherein it is easy for the "Chaoxing Fanya" platform to construct an intelligent learning space with characteristics of strong interaction, convenience and sharing, as well as rich resources for any course. This is a learning space that supports two-way interaction between teaching contents of teachers and learning outcomes of students and can make intelligent recordings of the learning process. The teaching alarm and learning monitoring function of the platform are beneficial to promote active learning.

3.2 Construction of the "internal-driving and external-guiding" learning mode in the "Chaoxing Fanya" platform

Based on the learning theory of "internal-driving and external-guiding" and combining with self-orientation features of intelligent teaching platform, the "internal-driving and external-guiding" learning mode was built in the platform (Figure 1). This mode centers at self-study activities of students and helps students to make and implement learning plans, evaluate learning efficiency, make self-reflection, and correct the learning plan through teaching guidance and support from the intelligent teaching platform.

Making learning plans. This stage is the basis for the follow-up implementation of learning activities and learning efficiency evaluation. Teachers analyze student situations according to the course contents of Technical Analysis of the Financial Markets, design self-study task list, upload learning resources and tests, and display task points clearly on the intelligent teaching platform to guide students in determining their learning objectives and making learning plans according to their conditions, thus helping them participate in learning activities better.

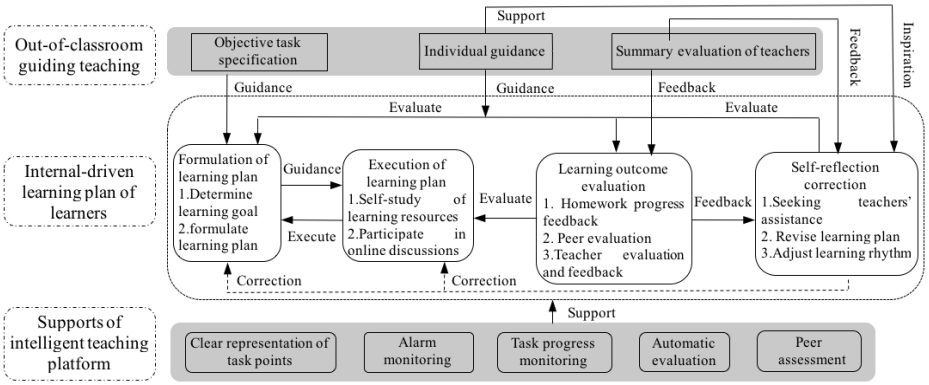

Fig. 1. Internal-driving and external-guiding learning mode of students on the Chaoxing Fanya platform

Implementation of learning plan. This stage is the key of "internal-driving and external-guiding" learning mode. Driving by the learning plan, students study learning resources by themselves and participate in online discussion and other activities. Teachers who serve as external guides provide individualized guidance through the alarm monitoring and task progress monitoring on the Chaoxing Fanya platform. For example, teachers can answer questions timely when they encounter difficulties, enlighten, and guide students toward solving problems automatically.

Evaluation of learning efficiency. This stage is not only the summary of making and implementation of learning plans, but is also the basis for the follow-up self-reflection and adjustment. The evaluation of learning efficiency aims to assess the learning state and knowledge mastery condition. It is mainly composed of homework progress feedback, peer comparison evaluation, and teacher evaluation feedback.

Among them, homework progress feedback is beneficial for students to make self-assessment. Peer comparison evaluation can help students recognize their gap with others. Teacher evaluation feedback helps students toward understanding themselves further.

Self-reflection and adjustment. This stage is the feedback results of students according to evaluation of learning efficiency. In this stage, students reflect and adjust the "internal-driving and external-guiding" learning process. After students discover existing problems through reflection, they can seek help from teachers and ask to give them some suggestions and emotional support. Students can make new learning plans according to the evaluation of learning efficiency and teachers' advices. Finally, students adjust learning paces flexibly according to their comprehension of knowledge.

4 Methodology

To test the reliability of the acquired 16-week course data, the reliability was analyzed first. On this basis, influences of internal-driving and external guiding strategies on learning efficiency, that is, independent learning ability, online learning behaviors and academic performances of students, were investigated through the "paired-samples T test".

4.1 Reliability analysis

Reliability of data collected from questionnaire survey was analyzed by a Cronbach's α. Reliability analysis aims to test whether the research data is real and reliable and whether respondents have answered the questionnaire [23]. The calculation formula of reliability analysis — Cronbach's α score is:

$$\alpha = \frac{K}{K-1}\left(1 - \frac{\Sigma S_i^2}{S_x^2}\right) \tag{1}$$

where α is the reliability coefficient, K is number of questions, S_i is the score variation of all respondents on the question I, and S_x is the variance of the total scores of all respondents.

Table 1. Meanings of numerical value intervals of Cronbach's

Cronbach's alpha	Internal consistency
α≥0.9	Excellent
0.7≤α<0.9	Good
0.6≤α<0.7	Acceptable
0.5≤α<0.6	Weak
α<0.5	Unacceptable

To assure the reliability of survey results, a stratified sampling method was applied for the questionnaire survey. A total of 50 students were chosen randomly from five classes. A total of 250 questionnaires were sent. The questionnaire was compiled according to the independent learning ability questionnaire designed by Zhu Zude et al. [24]. It comprised three dimensions of Attitude, Strategy, and Resource Utilization, and involved 41 questions. The five-point Likert scale was applied for quantitative scoring, while scores from one to five represented Completely Disagree, Disagree, Moderate, Relatively Agree and Completely Agree.

4.2 Analysis of paired-samples T test

A paired-samples T test was applied to verify the analysis of "internal-driving and external-guiding" learning in this study. The paired-samples T test aims to deduce whether a significant difference between mean values of two groups through the paired samples from these two groups has been observed. The paired-samples T test is different from the independent samples T test that it requires paired samples and sampling is mutually correlated, rather than mutually independent. Paired samples can be either two characteristics of an attribute of a case in the "pre-test" and "post-test", or descriptions of two different sides. The paired-samples T test calculates the differences of each team of observation values and then calculates the mean value of differences. Whether difference between mean values of two groups is significant is determined according to the difference between mean values of paired variables. It has a prerequisite that two samples must be paired and two groups and that these two samples from shall obey normal distributions. The calculation process is introduced as follows:

First, propose the null hypothesis. The null hypothesis of paired-samples T test is $H_0 : \mu_1 - \mu_2 = 0$, where μ_1 and μ_2 are the mean values of the first and second group, respectively.

Second, determine test statistics: t-statistics is calculated: $t = \frac{m}{s/\sqrt{n}}$, where m is the mean difference of samples, n is sample size, s is the standard deviation of sample difference, and degree of freedom df is $n-1$.

Third, calculate the observation values and probability (P value) of test statistics.

Fourth, determine the significance level α and make decisions. If the P value is smaller than or equal to α, the null hypothesis is rejected and it is believed that there are significant differences between the mean values of two groups. If the P value is higher than α, the null hypothesis is accepted and no significant difference between mean values of two groups would be observed.

5 Result analysis and discussion

In this study, 478 students of *Technical Analysis of the Financial Markets,* which was launched as an online common optional course for undergraduate's students, China in 2021 were chosen as respondents. These students came from six undergrad-

uate colleges in China. This course comprises 16 weeks of class hours and its content included three modules, namely, technical analysis of the financial markets, psychological management of transaction, transaction process and case study. The course data mainly covered measurement data before and after the questionnaire survey of independent learning ability, independent learning behavioral records of students, and daily academic performance data. The Chaoxing Fanya platform recorded the students' completion of task points, times of watching videos, online discussions, and other behavioral data. The quiz emphasized on examining the students' mastery of basic concepts and basic transaction processes. Quiz contents were determined according to specific courses of relevant modules, but difficulties were kept consistent.

According to the reliability analysis principle, the Cronbach's α value of the questionnaire was 0.893. The Cronbach's α values of Attitude, Strategy, and Resource Utilization were 0.885, 0.913, and 0.802, all of which were higher than 0.7. This reflected that the designed questionnaire had good reliability. The KMO value of the whole questionnaire was 0.870. The KMO value of Attitude, Strategy, and Resource Utilization were 0.884, 0.912, and 0.852, which were higher than 0.7. This indicated that the questionnaire had good structural validity. In this study, 250 questionnaires were collected, among which 238 were valid, thus showing an effective recovery rate of 95.2%.

The single-group pre-test and post-test research method was applied in this study. The "internal-driving and external-guiding" learning mode was used as the independent variable, while independent learning ability, academic performance, and independent learning behaviors were chosen as dependent variables. Teaching hours, teaching progress, and teaching content were used as the disturbing variables. To control disturbing variables in the experiment, the teaching hours, teaching progress, and teaching contents of six classes were assured to be consistent completely. The single-group pre-test and post-test process is shown in Figure 2. The pre-test was implemented on the 4th week, while the post-test was implemented on the 16th week.

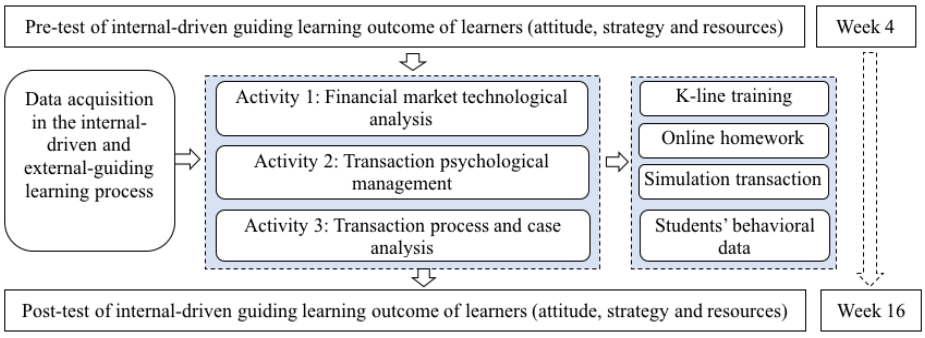

Fig. 2. Single-test pre-test and post-test process

5.1 Results analysis

The basic principle of "paired-samples T test" aims to analyze problems related to "internal-driving and external-guiding" learning on the Chaoxing Fanya platform. The results analysis is introduced as follows.

Analysis on the influence of overall internal-drive learning ability of students. The paired-samples T test was performed to the pre-test and post-test data of the internal-drive learning ability questionnaire to disclose changes in students' internal-drive learning ability before and after participating in the course Technical Analysis of the Financial Markets. Results showed that there are significant differences in term of Attitude (MD=0.1309, t=4.785, p<0.05), Strategy (MD=0.195, t=5.892, p<0.05), and Resource Utilization (MD=0.1309, t=5.956, p<0.05). Post-test scores are all higher than pre-test scores. This reflects that the intelligent teaching platform supports the "internal-driving and external-guiding" teaching mode, which generally improves the intrinsic independent learning ability. The students' performance in Strategy and Resource Utilization have improved significantly. However, the significance (two tails) of Attitude (t=0.269, p=0.818) is higher than 0.05, indicating the insignificant difference of Attitude between the pre-test and post-test. In view of mean values, the students' attitude (MD=0.008) is improved slightly.

Analysis on the effects of staged academic performances of students

Visual analysis of staged academic performances. To analyze the influences of "internal-driving and external-guiding" teaching on the academic performance of various classes in various stages, the staged academic performances of six classes are presented visually by broken line graphs. Figure 3 shows that test scores of students from all six classes have increased continuously, indicating that the academic performance of students are improving with the application of the "internal-driving and external-guiding" teaching mode supported by Chaoxing Fanya platform. There is an obvious fluctuation at T3, indicating that students might be in the adaptation stage in the early stage and academic performances of students in this stage fluctuate due to changes in course contents. As students adapt better to the "internal-driving and external-guiding" teaching mode, their academic performance may not fluctuate significantly with changes to course content. The "internal-driving and external-guiding" teaching mode can improve the staged academic performance of students significantly, but its influences tend to be stable after students adapt to the teaching mode. The "external guiding" design and teaching content design of teachers on the Chaoxing Fanya platform can stimulate the "internal drive".

Analysis on the effects of students' academic performances. To analyze the relationship between learning ability and academic performances, students were divided into two groups according to the mean values of pre-test data in the learning ability questionnaire. The students with intrinsic independent learning ability higher than the mean value were denoted as the high-ability group, while students with intrinsic independent learning ability lower than the mean value were denoted as the low-ability group. The independent sample T test was used to analyze changes in the academic performance of two groups in the pre-test and post-test. Academic performances of both high-ability group (MD=13.921, t=12.327, p<0.05) and low-ability group

(*MD*=14.2513, *t*=14.253, *p*<0.05) are improved significantly (by 13.921 scores and 14.2513 scores, respectively). Compared with the high-ability group, the low-ability group achieves more obvious improvement in academic performance. This not only verifies the validity of the "internal-driving and external-guiding" teaching mode to some extent, but also proves that this teaching mode is beneficial to improve the academic performance of the low-ability group.

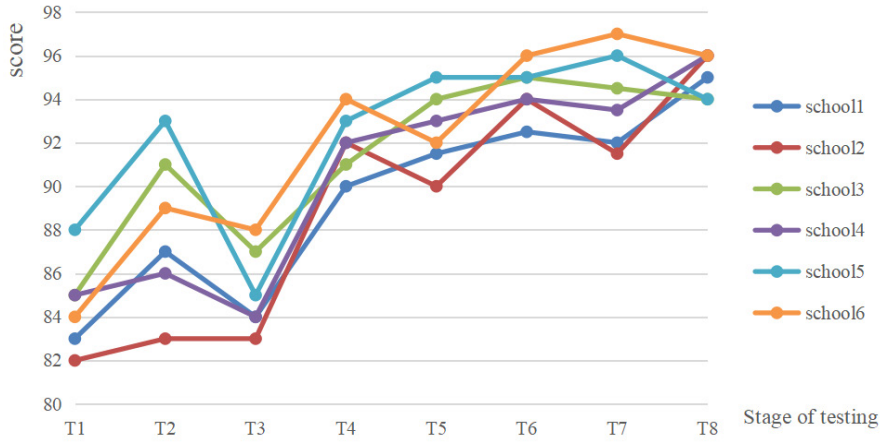

Fig. 3. Staged academic performances of students from 6 schools

Analysis on the effects of students' online learning behaviors and improvement degree of learning ability

Differentiation analysis of online learning behaviors. Online learning behavioral data, which was recorded automatically on the "Chaoxing Fanya" platform, was reviewed and screened. According to the classification indicators of online learning behaviors proposed by Xie Kui et al. [25], three online learning behaviors that reflect learning ability were determined, which were the task completion percentage, quiz score, and video watching hours. According to independent sample T test results, the high-ability group (*n*=83) generally present better online learning behaviors and the mean values of task completion percentage, quiz scores and video watching hours are higher than those of the low-ability group (*n*=105). There are significant differences between two groups in term of quiz scores (*MD*=5.16, *t*=5.881, *p*<0.05) and video watching hours (*MD*=39.12, *t*=2.229, *p*<0.05). However, no significant difference has been observed between two groups in terms of task completion percentage (*t*=0.252, *p*>0.05) and task completion percentages of both groups are close to 100%. Students with different intrinsic independent learning abilities can finish tasks assigned by teachers well during internal-drive learning. This indicates that the input degree of online learning behaviors can influence intrinsic independent learning ability of two groups to some extent.

Improvement degrees of independent learning ability of students with different intrinsic independent learning abilities. To analyze the influences of independent online learning behavioral input on improvement of independent learning ability of student

with various intrinsic independent learning abilities, variations of the general intrinsic independent learning, as well as Attitude, Strategy, and Resource Utilization (t=-4.123, p<0.05; t=-3.451, p<0.05; t=-2.123, p<0.05) were expressed by differences between post-test and pre-test. The significances are smaller than 0.05, indicating that there are significant differences. According to independent sample T test results, the independent learning ability of the low-ability group is improved more, but the independent learning ability of high-ability group is still higher than that of the low-ability group (strong independent learning ability in post-test). This reflects that during internal-drive self-orientation learning, the independent learning ability of low-ability students in Attitude, Strategy and Resource Utilization is improved faster, but their independent learning ability is still lower than that of students with high internally-driven independent learning ability after finishing the course.

5.2 Discussion

In the PST framework learning space, appropriate "external-guiding teaching strategy" is conducive to improve academic performances.

Strengthen intelligent emotional supports to students during learning. In the process of internal-driving and external-guiding learning, teachers provide accurate emotional supports timely, which can trigger positive perception experiences of students effectively. Moreover, emotional supports from teachers are an important content to stimulate and maintain learning motivations of students. Therefore, teachers can provide personalized feedback to students based on the strong interaction of intelligent learning space and multi-element emotional means supported by intelligent technologies.

In the late stage of "internal-driving and external-guiding" teaching mode, its effects on academic performances of students are weakened. For this reason, teachers can offer students diversified choices in the late stage by designing different combinations of external-guiding intelligent learning activities to further improve academic performances of students.

Provide timely and effective feedback to students with low intrinsic independent learning ability. High-efficiency feedback helps students to make accurate evaluation on their learning progresses, thus making them recognize existing gap and improve their behaviors and academic performances consciously. This can strengthen their internal drive to improve learning ability. Therefore, teachers are recommended to provide effective external-guiding feedback during independent learning of students with low intrinsic independent learning ability, such as timely and accurate feedback about learning tasks, learning process, independent learning strategy or methods. Moreover, explicit improvement suggestions are provided in the individual and visual manner to urge students to adjust learning behaviors and make academic progresses.

6 Conclusion

With the development of learning scientific and technological applications, applications of intelligent technologies such as data mining, learning analysis, and resource recommendation to the education field promote the development of external learning guiding strategies, while "external guiding" becomes an important means of realizing "internal drive".

In this study, an experiment was designed based on the "internal drive theory and instructor-led teaching principle". Learning ability, academic performance and online learning behaviors of students influence mutually as well as their relations during "internal-driving and external-guiding" teaching were investigated deeply using the "reliability theory and paired-sample T-test" method. The "internal-driving and external-guiding" teaching can improve independent learning ability of students, especially in dimensions of the Strategy and Resource Utilization in the PST framework learning space. The dimension of Attitude is not improved significantly, but the Resource Utilization is improved significantly after the implementation of "internal-driving and external-guiding" teaching mode. This reveals that resource utilization of ability type may be easily improved, while attitude of mental disposition-type might be difficult to be changed in a short period. The "internal-driving and external-guiding" teaching mode can promote improvement of academic performances of students in early stage, but its effect declines gradually with the increase of knowledge. Hence, some other teaching strategies have to be combined in the late stage to improve the academic performance of students further. Compared with students with high internally driven independent learning ability, the students with low internally driven independent learning ability have generally poorer online learning behaviors, especially in quiz scores and video watching hours. Nevertheless, no significant difference was observed between two groups in terms of task completion percentage. Learning ability of students with low internally driven independent learning ability has been improved, but their independent learning ability is still lower compared to that of students with high internally driven independent learning ability after finishing the course. This indicates that the internal-driving and external-guiding teaching is more appropriate to train students with low intrinsic independent learning ability. In the future, we can precisely design the introduction strategy in the PST framework learning space to stimulate the students' learning motivation and interest continuously.

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