The Design and Application of Intelligent Learning Support System Based on Knowledge Structure

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With the popularization of e-learning, Learning Support System (LSS) is playing an increasingly important role in teaching and the reform of education. Although pure resource-based LSS is prevailed, it cannot meet the needs of learning support in the era of big data and massive resources. Based on the teaching practice of LSS supporting computer courses in recent 10 years, and combined with the experience of optimizing LSS year by year, the intelligent LSS design with knowledge structure as the main body is proposed. And the LSS is optimized from five aspects, including micro-resource package structure oriented to knowledge points, knowledge structural reorganization of the learning resources, monitor and feedback learning behavior guided by visual theory of learning progress, resources recommendation based on the study progress and the knowledge structure, and reusing high-quality discussion posts and questions. Teaching practice has proved that the structured design of resource package can encourage imagination. Learning monitoring and feedback mechanism can maintain motivation and improve self-efficacy. Learning resource recommendation strategy plays a significant role in helping students focus on learning content and improve efficiency. High quality post is conducive to students’ deep learning.

Keywords: intelligent Learning Support System, knowledge structure visualization, visualization of learning progress, resource recommendation strategy

Introduction

With the popularity of e-learning, Learning Support System (LSS) is playing an increasingly important role in teaching and educational reform. Focusing on resource construction, paying no attention to learning behavior monitoring, and learning resource organization strategy, the mainstream LSS cannot adapt to the needs of learning support in the era of big data and massive resources. How to optimize LSS to better serve students’ learning behaviors and motivate students to work harder on online learning is an important part of...
The limitations of online learning are becoming increasingly apparent as the popularity of online learning. Compared with the construction of high-quality courses and MOOC courses, the effect of online learning is less than satisfactory. In addition to the students “individual inertia” and “passion course” factors, there are other reasons attribute to this phenomenon. The quality of the LSS and learning support ability are the main factors that influence the teaching effects, including unreasonable organization of the resources in the LSS, business development courses are not in conformity with the characteristics of learners, resources recommended way is completely in accordance with students’ preferences, etc.

Since entering the era of big data, connectionism’s view of knowledge and learning has prompted people to think seriously about the categories of knowledge to be learned and effective learning modes. Under the current historical background, learning platforms can be seen everywhere. It is very convenient to acquire knowledge by search engines, and learning resources can be obtained anytime and anywhere. However, this does not mean that students’ learning efficiency and quality can be greatly improved. In fact, the quantity and quality of learning resources are not the key factors that affect the current learning behavior and learning effect of students. “How to provide better learning support for students and prevent students from getting lost in the huge amount of learning resources? How to protect students’ initiative?” Such issues have become the urgent problems for the modern LSS to resolve. More specifically, this study aimed to answer the following three research questions:

1. How to ensure the original knowledge structure of course content and establish a learning resource group with knowledge system as the main body in the process of LSS construction?

2. How to provide better learning support for students in LSS learning activities to protect their learning enthusiasm, and constantly strengthen their learning motivation in the learning process?

3. How to establish a learning resource recommendation system centering on the knowledge structure, so as to ensure the completeness and stability of students’ knowledge system?

Literature Review

The Value of LSS in Modern Education

Modern educational teaching is inseparable from online LSS. The deepening of education informatization has provided a good material basis and technical support for the reform of teaching mode. Various new Internet-based teaching modes have mushroomed and grown rapidly. Massive Open Online Courses (MOOC), Small Private Online Course (SPOC), Flipped classroom mode, and discussion teaching are based on powerful LSS, relying on functions, such as “learning resource support” and “no spatio-temporal limitation in interaction and sharing” provided by LSS, it provides students with all-round learning support and plays an increasingly important role in improving teaching efficiency and optimizing teaching quality (Fan, Zhang, Bai, & Lin, 2012).

Modern teaching activities and reforms are inseparable from online learning and LSS. Internet-based LSS provides support for teaching reform in many aspects. From the teaching and research papers published by Chinese National Knowledge Infrastructure (CNKI) in recent five years, it can be seen that most of the teaching and research activities and papers are inseparable from LSS, which reflects the importance of LSS in modern teaching.
Teaching organization based on LSS has become the basic ability of teacher professional development. Online teaching based on e-learning theory has become an important starting point for front-line teachers to organize teaching activities and carry out teaching research and reform, and the ability to apply the information teaching environment has become an important content of teacher specialization. In the modern teaching environment, new teaching concepts and models based on LSS are constantly impacting the brains of front-line teachers, forcing front-line teachers to constantly adjust their teaching methods and habits to adapt to the goals of teaching reform and the LSS environment (Ma, Mao, & Wang, 2016).

Problems in the LSS

Classroom record video plays an insignificant role in daily teaching. Although classroom record video is very popular among MOOC course developers, most universities also regard video as an important part of MOOC course development. However, in the teaching practice, it is found that few students can watch the video of the whole class record step by step and word by word completely in the teaching practice, “fast forward” is a common mode of many students in a completely student-independent learning environment.

Linear stacked learning resources split the logical relationship between knowledge points. After investigating the mainstream LSS, the authors found that the vast majority of LSS still remained in the state of knowledge management. Just like 10 years ago, a large number of learning resources were stacked linearly in the learning platform. For students, linear stacked learning resources are convenient for sequential learning. However, at the same time, they also separate the internal logical relationship among cross-chapter knowledge points, which is likely to lead to the “fragmentation” of the knowledge system, and is not conducive to the formation of the overall knowledge structure of students, also the imagination and epiphany of students.

High-quality courses developed by commercial companies do not meet the needs of front-line teachers totally. Some LSS are designed and developed by commercial companies, and their interfaces and resources are beauteous. Because front-line teachers are not allowed to intervene in the design process and resource reconstruction process, the services provided by the platform do not meet the needs of front-line teachers totally and neglect the education rule.

Resource-based LSS discourages students’ enthusiasm due to the lack of learning behavior monitoring and feedback mechanism. At present, the vast majority of MOOC platforms and high-quality course platforms are based on resources. In the process of using this platform to carry out self-learning, the system does not record the learning process of students, and there is no feedback information for students. As a result, students feel that “learning is the same as not learning” because of no feedback information about their learning status, which dampens the enthusiasm of students seriously.

The knowledge recommendation strategy completely based on students’ preference does not meet the requirements of basic education. With the advent of the era of big data, a number of knowledge recommendation models that rely on the analysis of students’ learning behaviors and learning preferences have been cited by many LSS and become an intelligent learning model favored by teaching researchers. However, the authors believe that the knowledge recommendation model that completely relies on students’ knowledge preference can promote students to further develop their strengths, which is beneficial for education in higher education or postgraduate stage, but it is not suitable for basic education. The goal of basic education is cultivating “whole student”, and make up for the “short board”, so as to form a good knowledge base.
Therefore, in the LSS, for basic education stage students, the knowledge resources recommendation should not be based on the preference of students, but oriented to the knowledge structure and meet the teaching requirements of front-line teachers.

**Research Status at Home and Abroad**

High-quality LSS is the prerequisite for the smooth development of e-learning. The research on LSS construction starts from an early stage and has a history of more than 20 years. During this period, it has gone through several important stages from the development of ordinary courseware, creation of teaching situation, classroom record video, construction of micro-course resources, research and development of high-quality courses, construction of MOOC learning platform, construction of SPOC platform, and so on.

Judging from the construction process and theoretical results of LSS, most researches still focus on the construction of learning resources although for almost 20 years. Since the concept of MOOC was proposed, most LSS platforms actually have ignored the analysis of students’ learning situation and the management of learning behavior. Finally, they became several resource platforms based on classroom record video. In recent years, with the emergence of the concepts of intelligent learning, more and more scholars began to pay attention to the learning behaviors of students in LSS, and proposed several adaptive learning support models for students’ learning behaviors. However, from the perspective of the functions and applications of mainstream LSS, there is still a lack of large-scale LSS platform that is truly oriented to students and can reflect the progress of students in real time. It is found that relevant researches mainly focus on the following fields:


2. Research on the “electronic portfolio” of students. Wang Chun-yan (2010) researched “the establishment of learner files in autonomous learning”. Hasegawa and other researchers put forward that a LSS was proposed to enhance learners’ motivation (Hasegawa, Koshino, & Ban, 2015).

3. Resource recommendation technology based on learners’ learning preferences. Liu Zhong-bao and other scholars proposed “study on learner modeling and learning resource recommendation methods in the cloud environment” (Liu, Song, Kong, & Li, 2017), Lisa Fan mentioned the an AEH system, which can collect and the process the data about student goals, preferences, and knowledge to adapt the material being delivered to the educational needs of the students (Fan, 2010).

Despite these studies focus on the students’ learning situation from different aspects, still most of them stay in the theoretical research level, or guided by the theory of data mining, analyzing on existing data. Without integrating learning situation, knowledge structure, and teachers’ teaching ideas with LSS, they are short of empirical research based on large-scale learning behavior, and the universality and scientificity of the researches remains to be discussed.

**Research Design**

**Research Objectives and Positioning**

Firstly, intelligent LSS should be based on the knowledge structure of course content. Taking the
computer basic courses teaching with clear teaching objectives and clear teaching tasks as the research object, this study explores the LSS structure and function needed to achieve the expected teaching objectives. In primary education, students are expected to master all subtask of teaching objectives; the knowledge system is clear enough to learn. Therefore, in the construction of such LSS, the integrity and completeness of the knowledge system must be ensured, and the subject knowledge acquired by students must be complete and structured, and conducive to the future development and career requirements of students.

Secondly, intelligent LSS must be truly oriented to students and front-line teachers as follows:

1. Students are easy to get lost in massive resources in the era of big data, sometimes even feel awkward. Therefore, excellent navigation system and knowledge recommendation system based on knowledge structure are especially important to them.
2. Relevant research has found that, without effective feedback in autonomous learning, some students have “poor self-efficacy”, “loneliness and irritability”, “short attention span”, and other phenomena. Thus, the establishment of an effective learning behavior monitoring system and timely feedback of its effects to students are the problems that intelligent LSS must solve.
3. The best person who masters the course content and students’ learning situation should be the front-line teachers. The construction of navigation system and knowledge recommendation system should respect the front-line teachers and take their understanding of the course content and knowledge structure as the benchmark.

Research Content and Key Issues

Firstly, LSS should be established on the basis of adequate preparation of learning resources. According to the course objective, a database with guaranteed quantity and quality should be designed to meet the needs of teachers and students.

Secondly, in the process of LSS construction, the theory of knowledge visualization should be taken as the guidance to construct a structured micro-resource package that is conducive to enlightening thinking and stimulating motivation. In addition, it is necessary to change fundamentally the phenomenon of linear stacking of micro-resource packages based on the related results about the visualization theory of knowledge structure.

Thirdly, intelligent LSS should be oriented towards students and truly serve front-line teachers. In order to protect students’ learning enthusiasm and warn a small number of students about their “lazy” behaviors, it is necessary to feedback their learning progress to every student in time. Feedback mechanism is of great significance to maintain students’ learning enthusiasm. And those detailed records of each student’s learning behavior can also provide data support for teachers to analyze students’ learning behavior, and carry out teaching research to improve teaching mode.

Then, intelligent LSS should have resource selection and recommendation mechanism. The recommendation algorithms in business and some teaching fields are designed according to the preferences of students (or customers), and cannot meet the needs of basic education. The authors think that the effective recommendation technology should be oriented to the knowledge structure, and the knowledge that students need to master should be recommended according to their learning deficiency. Therefore, this research focuses on exploring the automatic recommendation algorithm based on knowledge structure and learning situation, supplemented by teacher recommendation technology.
Finally, the discussion posts published by students in different years for the same learning content have great similarities, and their difficulties and problem-solving ideas are also very similar. Therefore, we should try our best to reuse the best posts of senior students, so as to lead current students to think and promote their more comprehensive and in-depth learning.

Research Plan

Based on the teaching platform of the basic computer course of Beijing Normal University (see http://cen.bnu.edu.cn), this action research has been carried out for many years. After several rounds of exploration and reflection, an effective conclusion has been gradually formed. Firstly, a preliminary model of resource composition was formed based on literature analysis and interviews with front-line teachers. Then, the existing teaching platform is used to organize micro-resource packages to prepare for teaching practice activities. Third, the research group developed the learning behavior record function in this platform, so that
each student’s learning behavior can be recorded in detail. Fourth, the research group carried out teaching practice activities and extracted some learning behavior records from the platform to obtain first-hand data. Fifth, according to the feedback information, the research group further optimized the model structure. Sixth, the authors reorganized and reconstructed learning resources, developed and improved platform functions, and prepared for the next round of research. After several rounds of iteration and optimization, the research conclusion can reach a more scientific and objective level.

Research flow chart. The key links involved in this research and the research control are shown in Figure 1.

Research objects and implementation. Based on the teaching platform, students have computer classes on it, those courses including “Multimedia Technology and Web Design”, “Data Analysis Methods and the Application”, and “Information Processing Foundation”. Based on nearly 10 years of teaching practice to this platform optimization and iteration step by step, made its structure and function perfect year by year, it finally reached the ideal state.

Structure Design of Intelligent Learning Support Platform

Structured Micro-resource Package Design and Its Necessary Structure

The deficiency of LSS containing only micro-video. With the popularity of mobile learning, micro-video has been attached great importance to teaching and research in recent years. On the basis of fully affirming the significant effect of micro-video on extracurricular independent learning support, the authors also found the deficiency of relying on micro-video to support independent learning.

1. Students need graphics and textual resources as well as micro-video. Some students reported that it was not convenient to find the solution method directly from micro-video when they encountered difficulties in practical class;

2. Operation materials are expected to meet the needs to operation skills synchronously;

3. Some students hope that the resource pack can provide diagnostic questions very similar to the cases, so that they can detect the learning process independently in a timely manner.

In conclusion, students believe that the learning support provided by micro-video is far from enough, and micro-courses should be carefully designed. And it is necessary to optimize the existing learning support environment from the aspects of teaching process, internal structure of micro-course resources under the guidance of instructional design (Zhao, 2009).

![Figure 2. Components of micro-course resources and internal structure diagram.](image-url)
The strategy of structuring the micro-resource package. Based on the properties of micro-course, and connecting with the needs of “micro-video with graphic material”, “supporting materials”, and “supporting self-diagnostic exercises” and other requirements under the guidance of modern teaching design theory, the authors focus on the exploration of the components and structure of micro-course resources and put forward the relationship diagram of the components and internal structure of micro-course resources, as shown in Figure 2.

In the whole resource composition of micro-course, micro-video is still the core. In order to achieve better learning effect, the authors have added some new content in each micro-resource package. Firstly, the relevant graphic and text materials of each micro-video can help students find key indicators and details faster. Secondly, supporting self-diagnosis exercises. The self-diagnostic questions should be highly similar to the cases to help students verify whether they have mastered the knowledge and find out the deficiencies in learning. Thirdly, providing operating materials respectively. For practical operation questions, the supporting materials provide the possibility for students to imitate and practice according to the content of micro-video. Finally, several thinking questions are provided to guide students to reflect on the whole case content from a higher level and play a role of summary.

Realization and teaching practice of micro-resource package structure. Based on the structure of the micro-resource package shown in Figure 2, the authors supplemented supporting graphic and text materials, original operating materials, and self-diagnostic test questions for each teaching case (micro-video) on the teaching platform, and formed a relatively complete micro-resource package. In addition, in order to locate learning content better and inspire learning motivation, each micro-resource package is equipped with question-centered and enlightening thinking questions, which have supported the “Multimedia Technology and Web Design” course for three years (from 2010 to 2013).

Resource Package Reorganization Scheme Guided by the Visualization Theory of Knowledge Structure

Design of reorganizing micro-resources based on the visualization theory of knowledge structure. In view of the phenomenon of “knowledge fragmentation” of micro-course, the authors provide knowledge map, with micro-resource package on its nodes; it highlights the logical relationship between knowledge. Finally, we formed the three-dimensional link of the micro-resource package and realized the visualization of the knowledge structure.

This study focuses on five problems:

1. Analyzed carefully and decomposed the teaching objectives, and formed a number of valuable teaching cases.
2. Guided by the theory of knowledge visualization and mind mapping, using mind mapping tools, drawing the concept map of each chapter, which taking the knowledge points as the nodes and link the micro-resource package as the attachment of the knowledge points.
3. Added “learning guidance” module, for the import of learning content.
4. Reconstructed the content of the question. In the thinking questions of each micro-resource package, one summary question oriented to the current knowledge point is reserved, and one question oriented to the subsequent content of this knowledge point is added. The new question should be illuminating and leading, and combined with the following knowledge of the case guide learning.
5. Developed cross-micro-course and cross-chapter comprehensive exercises, to investigate students’ comprehensive application ability, promote students to form a holistic knowledge structure, help students build
up in line with their cognitive habits of knowledge system, and to promote students to form a holistic, systematic knowledge structure (Ma, Zhao, & Zhu, 2013).

The structural relationships of micro-resource packages that enhance knowledge connectivity are shown in Figure 3. Each knowledge point is a node of the concept map (That is, the “micro-course package” tag in Figure 3), which takes the name of the knowledge point as the hyperlink of the tag. When the student’s mouse hovers over the node marker, the suspension window as shown in “micro-course package 7” will pop up automatically, which contains all hyperlinks (i.e., micro-resource package) related to the knowledge point (Zhao, 2012). The arrow lines between the micro-resource packages express the precursor or successor relationship between micro-course and the internal logical relationship is constructed by the thinking questions and learning guidance inside the adjacent resource packages. The “cross-knowledge point synthesis question” based on multiple micro-course packages consolidates the internal logical relationship among micro-resource packages, and its topic is usually of high difficulty, which requires group collaboration to organize teaching activities to achieve learning objectives.

![Figure 3. Schematic diagram of micro-resource bundle organization to enhance knowledge connectivity.](image)

**Implementation and teaching practice of knowledge structure visualization.** According to the above guidelines, the authors have completed the micro-resource package organization system guided by the visualization theory of knowledge structure in the teaching platform. The knowledge structure diagram of the “image processing module” in the course of Multimedia Technology is shown in Figure 4. In the teaching platform, the authors present the knowledge structure of this chapter with the concept map as the navigation map of this module. Mark the knowledge points with “?” in the module and hyperlink the micro-resource package to each knowledge point (when the mouse hover over any knowledge point, a suspension window containing all the internal resources will pop up).

**Knowledge Management Solutions That Focus on Interactive Value and Reuse Quality Arguments**

Years of online teaching practice have been found that discussion posts published by students in different years for the same learning content have great similarities. Also, the difficulties they came across and problem-solving ideas are no different. In 2016, based on this idea, the authors began to think about how to
utilize the essence of predecessors in the micro-resource package and tried to construct a high-quality micro-resource package containing the excellent thinking process and results of predecessors.

2. Image processing technology

When you hover over any of the “?” The system will pop up a menu (when the mouse pointer points to the [close] button in the menu, the current menu can be closed). Use the menu can be related to the knowledge of micro video, view the text of the key steps, and can be generated for the knowledge of the works submitted to the system, so that the teacher in time to understand your progress.

Building a new resource package containing previous excellent achievements. In order to support students’ online collaboration, the authors developed online interaction function (namely, teaching forum) in teaching platform in 2007, which allows students to post in the teaching forum when encountering difficult problems, and encourages other students to participate in discussions actively. In the early stage of the teaching forum, the number of posts in the teaching forum was small and the quality of posts was fair. After 2010, in order to ensure the neat and authority of teaching forum, the authors began to require students to post in their real names and participate in the discussion in the teaching forum, which greatly improved the quantity and quality of posts. After years of accumulation, this teaching platform has accumulated a considerable number of discussion posts.

Analyzing these posts, the authors further constructed the internal structure diagram of the micro-resource package containing the discussion and collaboration results of predecessors as shown in Figure 5.
The implementation and teaching practice of reusing quality posts and questioning points. Based on the above assumptions, the authors began to try to screen and classify the existing elite posts on the teaching platform in 2016, and then packaged them according to the keywords in the posts and linked them to the corresponding knowledge points in the knowledge map. At the same time, in order to make full use of the results of students’ collaborative learning, the authors also collected the hot issues (quality query points) left by students when they participated in the class discussion, and linked them to the relevant knowledge points in the knowledge map (Ma, Yue, & Jiang, 2015).

Teaching practice has found that the reuse of quality stickers plays a significant role in students’ rapid acquisition of comprehensive knowledge and deep thinking.

Construct an Effective Information Feedback System of Learning Situation

As for the common problem of “low completion rate” among MOOC students, the authors believe that “short attention span and unsustainable effective learning” is the key factor, and the “lack of feedback mechanism and teacher-led” online learning environment is the root cause of this phenomenon. Therefore, the authors put forward the idea that “strengthening teacher-led, giving real-time feedback, and strengthening positive motivation” for online mobile learning behaviors.

Design of information feedback of learning situation. Learning behavior monitoring and recording capabilities have been embedded in learning platforms since 2009. The data collected by platform including the information about watching video, using graphic resources key point of information (starting time and duration, usage of the IP address about the equipment, etc.), while the information only serves the teacher after class analysis, and there is no feedback to students.

In order to solve the problems of “insufficient attention persistence” and “students often ‘fast-forward’ to online video”, it is necessary to timely feedback their learning behavior and learning status to students. In 2012, the visualization module of learning progress was finally completed. The specific implementation strategies are as follows. Firstly, the learning platform should record automatically every learning behavior information of each student, and generate mainly two types of data: reading score and self-diagnosis score. The so-called “reading score” refers to the starting time and time for each student to watch micro-video, the starting time and time for reading graphic and text materials, and the corresponding results of the two parts. Self-diagnosis score
refers to the time and score of students doing self-diagnosis questions after class. Secondly, when a student logs into the learning platform, the system extracts automatically the two sets of scores of the student at each knowledge point, and then draws them on the knowledge map in the form of visual illustration, so as to express the students’ learning level at each knowledge point (Ma et al., 2013). For this technical scheme, the author calls it “learning progress visualization”.

**Visualization of learning progress and teaching practice.** In order to reflect the learning progress of students in various knowledge points vividly, the authors divided the learning progress of students in knowledge points into 10 levels, with 10 different signals to express the state of students’ learning level (bulbs of different brightness, ice cream, diamonds, crowns, etc.). The visual diagram of the learning progress of Zhang Xiao-ping (a student of studying Multimedia Technology) in the “Web design technology” module of the Multimedia Technology course is shown in Figure 6.

In the knowledge map shown in Figure 6, the light bulb mark of each “?” can reflect the learning progress of Zhang Xiao-ping intuitively (the light bulb brightness and special graphics in Figure 6 reflect Zhang Xiao-ping’s learning level at various knowledge points).

Teaching practice has demonstrated that the introduction of visualization of learning progress enables each student to know his/her own shortcomings timely and urges students to invest more time and energy in the shortcomings. In addition, this timely feedback mechanism enables students to truly feel teachers’ attention, improves their sense of learning efficiency, and plays a significant role in maintaining students’ strong learning motivation.

**Establish a Resource Recommendation System Based on Learning Information and Knowledge Structure**

**Design of resource recommendation algorithm.** In basic education, most of the knowledge that students need to master is compulsory. Instead of recommending learning resources based on students’ personal preference, learning resources should be recommended based on knowledge structure and resource relationship. In order to ensure that students can learn the most appropriate knowledge in the right time, the authors adapt the method of “system automatic recommendation” and “teacher recommendation” to recommend required learning resources to students.

The so-called “system automatic recommendation” is a resource recommendation strategy implemented by the platform based on the backstage recording information of students’ learning behaviors and students’ scores at various knowledge points, in accordance to the learning cycle specified by the teacher. The specific methods are as follows. Firstly, at the beginning of the semester, the teacher makes a preliminary assessment of all the resources in the course, classifies them according to their importance and quality, and sets the resource weight and wipes out some inferior resources. Secondly, the teacher needs to make a prediction about which period of time each resource should be distributed to students, and write the prediction time into the field “should learn date” in the backstage database. Thirdly, in the teaching process during the semester, whenever a student logs on to the learning platform, the system will extract automatically the learning behavior and score of the student at each knowledge point, and resources that match the “should learn date” with the current date and score lower than the specified standard will be directly recommended to the current student. This is a resource recommendation strategy based on the elements of knowledge map, resource level, students’ learning progress, and the date of learning resources.
5. Web design techniques

This module is mainly used to reflect your learning situation. For each map in knowledge, the location of the tag [?] is loaded with micro video and text materials that you need to learn under the navigation module. In this regard, you need to watch the micro-video, micro-video comments, complete the production of works and submit works. The system will be evaluated according to your performance. If your learning at this node has met the requirements, the system will turn on the yellow light or the lights will go out. If you look at the lights on the map, will know what knowledge nodes you need to continue to work on.

The so-called “teacher recommendation” refers to that in the teaching process, teachers recommend certain resources directly to students from the learning platform according to their own teaching design and students’ learning status, and require students to complete relevant learning tasks within the specified time.

The resource recommendation system should respect the teachers’ experience, so “teacher recommendation” resources take precedence over “platform automatic recommendation” resources.

**Design and teaching practice of resource recommendation algorithm based on knowledge structure.**
The authors set up specially the “Today I learn” module in a prominent position in teaching platform, which is divided into three blocks, namely “list of learning resources”, “list of expired learning resources”, and “list of learned resources (within this week)”. The “list of learning resources” lists all resources recommended by teachers or by the platform in this week, which have not yet reached the learning standards. These are all learning tasks that students should complete in this week. If a student fails to complete a certain resource in the “list of learning resources” within this week, the resource will automatically fall into the “list of expired
learning resources” next week, and it is still hoped that the student can make up the missed time. If a student learns a certain learning resource actively and reaches the specified learning standard, the resource will be automatically transferred from the “list of learning resources” to the “list of learned resources”.

Zhang Xiao-ping, a student of the course of Multimedia Technology, logged on the learning platform on March 11, 2017 and obtained the “Today I learn” interface as shown in Figure 7.

![Figure 7. Resource recommendation status in week two of “Multimedia Technology” course.](image)

**Application and Evaluation of Intelligent LSS**

**Teaching Practice Based on Intelligent LSS**

Founded in 2003, Beijing Normal University computer basic course teaching platform (SEE http://cen.bnu.edu.cn) provides support for more than 2,800 students’ independent learning in and out of class every year. The platform has been under construction ever since, which has experienced several stages including “simple classroom record video construction” and “micro-video construction” to “micro-course construction”, “the reorganization and reconstruction of micro-resource package guided by the knowledge structure of visualization” and “construction of monitoring and feedback mechanism guided by the learning process visualization”, “focus on the quality of interaction and social knowledge construction”, “learning resources recommended on the basis of the knowledge structure”, and so on. During the application process of the platform, the authors always insist on guiding the construction of the platform with the theory of knowledge construction, taking the teaching practice as the standard to test the new function of the platform, and gradually optimizing and perfect the platform.

In the past nine years (since 2009), the authors have led the teaching team to carry out a series of teaching activities on the learning platform, taking the teaching practice of “Multimedia Technology and Web Design”, “Data Analysis Methods and Applications”, “Information Processing Foundation”, and other courses as the research object. In order to meet the needs of teaching research and platform improvement, three to four classes
are selected every year to organize teaching practice and extract the record information of learning behavior from the backstage. Then, these practical data are used to conduct induction and analysis, and the structure and function of the platform are gradually optimized according to the analysis conclusions.

**Application and Effect Analysis of the New Platform**

**Analysis of the effectiveness and experience of structured micro-resource packages.** Based on the micro-resource package structure shown in Figure 2, the authors carried out a three-year teaching practice (2010-2012), mainly providing support for students’ independent learning after class and the promotion of flipped classroom teaching mode in some chapters. At the same time, statistical data of students’ usage of various learning resources were collected, and students’ experience of independent learning with structured micro-resource packages was obtained through questionnaires and key interviews.

In 2013, two classes with no significant difference learned the “image color adjustment” module in the learning platform. Statistical data of all kinds of micro-resources used by students online are shown in Table 1.

**Table 1**

<table>
<thead>
<tr>
<th></th>
<th>Independent learning support after class (97)</th>
<th>Flipped classroom teaching mode (105)</th>
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<tbody>
<tr>
<td></td>
<td>Micro-video</td>
<td>Graphic material</td>
</tr>
<tr>
<td>Num-</td>
<td>Duration</td>
<td>Num-</td>
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<tr>
<td>Beg.</td>
<td>21</td>
<td>87</td>
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<tr>
<td>Mid.</td>
<td>35</td>
<td>265</td>
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<tr>
<td>The end</td>
<td>78</td>
<td>623</td>
</tr>
<tr>
<td>Total</td>
<td>134</td>
<td>975</td>
</tr>
<tr>
<td>Per.</td>
<td>1.38</td>
<td>10.1</td>
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</tbody>
</table>

**Note.** The beginning refers to the initial period of the module, the middle period refers to the middle period of the module, and the end period refers to the period near the end of the module. The unit of time is minutes.

Judging from the data in Table 1, the authors made the following conclusions:

1. Micro-video has an obvious effect on students’ independent learning, but the forms differ in different types of learning modes. In the flipped classroom teaching mode, micro-video mainly plays a role in the early stage of learning, while in the after-class independent learning support mode, micro-video learning occurred in the whole learning cycle.

2. In the independent learning based on micro-resource package, although micro-video is prevailed, graphic, and text materials also have a high utilization rate. No matter flipped classroom mode of teaching or students’ independent learning after class, the total number of visits to graphic and text materials exceeded micro-video. Students tend to get access to graphic and text materials in the period of the middle and late, which depicts that at the beginning of the learning activity, most students prefer watching micro-video. In the middle or the end of the learning, students already have a basic grasp of learning content, graphic and textual material will be more convenient and more accurate for further study.

3. Students’ access to graphic and textual materials and the use of self-diagnostic questions have a complementary relationship. That is to say, the difficulty of self-diagnosis questions and the usage will affect directly the usage of graphic and textual materials, but will not affect the usage of micro-video.

4. Graphic and textual materials are more efficient for solving doubts and master details. As Table 1, although the duration time for students to visit graphic and textual materials is less than that of visiting...
The interview data of the students also confirmed that: In the process of solving the questions (self-diagnosis questions), most students would check directly the graphic and textual materials if they encountered any doubt or inaccurate parameters, instead of re-viewing the micro-video. Therefore, although the visiting time of graphic materials is less than the viewing time of micro-video in the long run, students can gain a lot of knowledge through graphic and textual materials.

Analysis of the effectiveness and experience of knowledge structure visualization on teaching. Based on the theory of knowledge visualization, the authors have completed the reorganization and reconstruction of micro-resources of several courses, and supported the teaching of basic computer courses from 2015 to 2016 with the new micro-resource system, and achieved good teaching results.

In order to understand fully the effect of the micro-resource system guided by the theory of knowledge visualization, the authors collected the use experience of students with questionnaires and interviews. Students generally believe that:

1. Concept map, as a navigation map organization system of the resources, can help students understand each bundle of prior and subsequent knowledge, and prompt students’ knowledge-transfer and imagination, so as to avoid the learning disabilities caused by insufficient knowledge of advanced study.

2. The guide learning plan and thinking questions in the micro-resource package play a role in the transition and bridge between the micro-resource package and it is very important to inspire thinking, guide learning, and understand the relationship between knowledge points.

3. Presenting the knowledge structure with the concept map for the knowledge structure visualization is conducive to students from the overall grasp of the whole chapter of all the content, convenient for students to find timely their own knowledge system deficiencies and check the gaps.

4. It is an effective means of navigation that forming a three-dimensional (3D) link of the micro-resource package and achieving the integration of micro-resource package management through the micro-resource package linking to the corresponding node in the knowledge map.

The schematic visualization of knowledge structure can help students understand the internal logical relationship between relevant knowledge points and promote students to transfer from one knowledge point to another, and even trigger imagination and epiphany (Ma et al., 2015), reducing the occurrence of student knowledge fragmentation, and is conducive to the formation of students’ integrity and overall knowledge structure.

Analysis of the effectiveness and experience of visualization of learning progress. Combined with the phenomenon of “low extremely course completion rate” commonly existing in MOOC learning, the authors believe that for the public groups with neither external pressure nor a wide gap in knowledge base, high-quality online resources may ignite instantly the passion of students, but such passion is not enough to maintain the integrity and continuous completion of a course (Ma, Zhao, & Wu, 2013). The introduction of visualization of learning progress prompts some students to overcome “inertia” and promotes greatly students’ learning enthusiasm.

From the backstage database of the learning platform, the authors extracted the data of students of two classes in the Spring of 2014 (monitoring and feedback—the experimental class) and the Spring of 2013 (monitoring but no feedback—the control class) who watched micro-video independently outside class in the “image color adjustment” module of Multimedia Technology course, as shown in Table 2.
Table 2

**Statistical Data of “Image Color Adjustment” Module Micro-video for Two Types of Students**

<table>
<thead>
<tr>
<th></th>
<th>In 2014 (202 students—feedback)</th>
<th>In 2013 (215 students—no feedback)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mobile equipment</td>
<td>Computer room desktop</td>
</tr>
<tr>
<td>Gross impression</td>
<td>626</td>
<td>197</td>
</tr>
<tr>
<td>Over half of the time</td>
<td>344</td>
<td>93</td>
</tr>
<tr>
<td>Full attendance</td>
<td>173</td>
<td>71</td>
</tr>
<tr>
<td>Total length (minutes)</td>
<td>2,207</td>
<td>769</td>
</tr>
<tr>
<td>Average duration of a single run (minutes)</td>
<td>3.53</td>
<td>3.90</td>
</tr>
<tr>
<td>The per capita time (minutes)</td>
<td>10.9</td>
<td>3.81</td>
</tr>
</tbody>
</table>

Table 2 shows that:

1. Students in the experimental classes (with feedback mechanism) using LSS to participate in extracurricular length per capita and per capita number of online autonomous learning had the very big promotion, especially mobile learning “single all length” index rose to 3.53 from 0.78 minutes, complete watch micro-video from two times up to 173 times. It reflects that under the feedback system, the amount of input and attention of students using LSS to carry out independent learning have been greatly improved.

2. The length of time that the experimental class students use micro-video to carry out extracurricular independent learning has been significantly increased. Whether it is online viewing micro-video conducted by campus public computer room or independent learning conducted via mobile devices, the learning time of each student has been increased significantly.

3. According to the students’ homework and performance in class questioning, the experimental class students have a more accurate grasp of operating procedures and skills, and the polarization of students is also contained. During the whole semester, no more than five students in the experimental class of the learning platform who watched micro-video compared with 18 students in the control class.

Through the feedback mechanism, every student has the external pressure and the urgency of learning. It also enhances their sense of self-efficacy and improves their initiative in learning. Therefore, it is obvious that monitoring and feedback mechanism are effective in learning. Questionnaire survey and interview for students also confirm this point.

**Analysis of the effectiveness and experience of learning resource recommendation.** The learning resource recommendation function is a module developed by the learning platform at the end of 2016, only one semester of teaching and research data have been accumulated currently. According to the learning behavior records of the learning platform, owing to the introduction of the recommendation mechanism, students tend to watch micro-video at fixed time and are likely to choose the same video. In addition, they spend more time on the recommended video than other micro-video.

According to the final learning effect of students, most students are more organized and considerate in answering class questions after 2015. In 2013 and before, most students answered classroom questions on a scattered view, and usually did not take into account the relevant content of previous chapters. However, the students’ organization and integrity in answering questions were significantly improved after 2015. At the same time, the quality of students’ works under the group collaboration mode has also been improved greatly in the past two years.
In addition, judging from the students’ view about teacher at the end of the semester, students’ satisfaction with the three courses (“Information Processing Foundation”, “Multimedia Technology and Web Design”, “Data Analysis Method and Application”) in 2016 reached 4.95 points or more (full score of 5 points), which demonstrated the value of this LSS at some extent.

**Suggestion and optimization idea of learning resource recommendation algorithm.** The recommendation of learning resources is only “platform automatic recommendation” and “teacher recommendation” currently. In the near future, the authors will attempt to “students’ mutual recommended” function that requires students to imitate the teacher recommended to other students learning resources, encouraging students to analyze the internal logic relations among the knowledge points in the process of recommend resources and realizing the process from knowledge sharing to knowledge creation, so that learning can reach a deeper level quickly (Ding & Wang, 2017).

**Conclusion**

Modern educational reform guided by e-learning theory and the LSS go hand in hand. Flipped classroom, MOOC, SPOC, and project-based teaching are all based on LSS. However, apart from great achievements in resource construction, LSS has made little progress in structural design, learning behavior monitoring, feedback and knowledge recommendation in recent 10 years. From the exploration and teaching practice in LSS construction in recent eight years, it can be seen that the structured design of learning resource package and the visual presentation of the logical relationship between learning resource package play an obvious role in promoting students’ association and imagination, realizing the consistency of knowledge and promoting meaningful construction, which are important links in the development and design of LSS. The functional design of learning behavior monitoring and feedback mechanism is very necessary to solve students’ learning inertia, improve their learning efficiency, and maintain motivation. Taking students’ learning progress as the benchmark, considering comprehensively the knowledge structure, learning period, and teachers’ suggestions, and constructing the learning resource recommendation system in the learning platform plays a significant role in helping students focus on learning content and improving learning efficiency (Ding, Zhang, Sang, Jin, & Zhang, 2016). The reuse of high-quality posts based on the discussion contents shared by senior teachers can help current students grasp the key points of learning quickly to think about problems from a broader dimension and contribute to deep learning.

**References**


