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Research and Implementation of U-Learning System Based on Experience API

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Abstract
Experience API provides a learner-centered model for learning data collection and learning process recording. In particular, it can record learning data from multiple data sources. Therefore, Experience API provides very good support for ubiquitous learning. In this paper, we put forward the architecture of ubiquitous learning system and the method of reading the learning record from the ubiquitous learning system. We analyze students' learning behavior from two aspects: horizontal and vertical, and give the analysis results. The system can provide personalized suggestions for learners according to the results of learning analysis. According to the feedback from learners, we can see that this u-learning system can greatly improve learning interest and quality of learners.

Keywords
Activity Analysis, Experience API, Learning Behavior, Learning Record, LRS, Ubiquitous Learning

1. Introduction

In the past decades, information technology has been developing continuously, and it has been playing an increasingly prominent role in education. There are many changes in educational domain caused by the development of Internet technology, multimedia technology and e-learning platform. The learning mechanism of teaching system has begun the development and progress from e-learning to m-learning and even to ubiquitous learning (u-learning for short). U-learning is becoming an important way to achieve lifelong learning. More and more scholars' attention has been drawn into it. In 2013, Advanced Distributed Learning (ADL) released Experience API (xAPI for short, also known as Tin Can API), which allows learners to enjoy u-learning services and resources [1]. The Experience API is a new specification that is part of the newly initiated ADL Training and Learning Architecture (TLA).

The xAPI provides a learner-centered model for learning data collection and learning process recording and it can record learning data from multiple data sources in particular [2]. It breaks away from the traditional mode of learning record collection which relies entirely on a single LMS (learning management system) platform, and is also suitable for supporting u-learning, especially social learning. In order to realize the ubiquitous learning, it is urgent to construct an adaptive learning system to reduce learners;

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time in finding appropriate learning resources and learning services. In this paper, we develop and implement a u-learning system based on Experience API, and propose an adaptive learning solution of u-learning.

2. Overview of the Experience API

The Sharable Content Object Reference Model (SCORM) was developed and published by the ADL project team in 1997. The standard has been widely used in the field of e-learning and has rapidly become a de facto standard in this field. However, some defects are starting to come up with the development of e-learning and learning technology. For example, it cannot meet the needs of personalized learning because it is on one-way information transfer mode. The SCORM standard accesses and tracks learners' learning status data by using LMS [3]. It can only get limited learning status data such as test scores or course completion status. Nowadays, educators and learners need to more learning data to obtain personalized learning services. They expect formal and informal learning, including using social networks to study. Learners want their learning to be recognized, whether through LMS or by any other means. This is a challenge for learning based on LMS. Compared with the SCORM, the Experience API provides more powerful capabilities for learners and educational developers in tracking and recording learning data.

The data from social media such as Facebook or Twitter is delivered as "streams" that can be used and aggregated by many websites and applications. The Experience API generates and captures learning flow data and then organizes the data into meaningful learning content. It is a good way to encapsulate and exchange learning data by using a learning-based activity stream. These activity stream data include defined participants, verbs, and activities associated with learning experience so that the exchanged data retains contextual meaning. A simple example of an activity flow associated with learning based on LMS is: I (participant) complete (verb) information security course (object) [4]. An example of informal learning scenarios could be: Tome (actor) delivering (verb) comments (object) at the student forum of the project management course [4]. To meet their specific needs, different areas (e.g., the medical community, government, higher education) develop corresponding options for each of these three elements.

Another element of the Experience API is the Learning Record Store (LRS), which is based on ADL, tracking and storing components based on service methods and TLA [5]. The flexible LRS system is designed independently of the platform, which can be either a stand-alone system or a component of a traditional LMS. The goal of TLA is to make the Experience API compatible with SCORM, which ensures neutrality of the platform, supports offline learning and learning out of the browser [6].

LRS will build a customized TLA service suite with content brokers, user profiles, and additional services of capability networks [7]. In addition, LRS allows authorized systems to retrieve previously recorded activity stream statements, which makes it possible to develop advanced third-party reporting and data analysis tools. Experience API is not only suitable for individual learning, but also for team learning, collaborative learning and teacher-intervened learning, which can support the group learning, informal learning and social learning in any device or platform.

3. Overview of U-Learning Systems

U-learning evolved from the word ubiquitous computing. U-learning is proposed by American scholar Mark Weiser in "The Computer for the 21st Century" in Scientific American in 1991. The u-learning, which is ubiquitous in learning, is a way of learning which is further developed of the learning methods of digital learning and mobile learning. It has been widely concerned by researchers at home and abroad. The learning style of u-learning avoids the shortcomings of the resource-oriented and low-resource sharing in the past, and emphasizes the reusability, collaboration, adaptability and granularity of learning resources. The u-learning system is not a simple resource repository or a learning platform, but an intelligent learning environment with the ability of situational perception. It provides different learning support for different students. Anyone may enter the formal or informal study at any time and any place. The learning process is semantic integration, context aware-ness, and so on. When designing the u-learning system, there are three things to be considered. First, u-learning system should be able to provide adaptive learning resources based on learners' characteristics, such as learning styles and cognitive level. second, teachers should be able to track the learning progress of learners, adjust teaching activities and evaluate learning outcomes. third, it can support independent learning, collaborative learning and team-work. The u-learning system supports developers to develop courses. The u-learning system structure model is shown in Fig. 1.

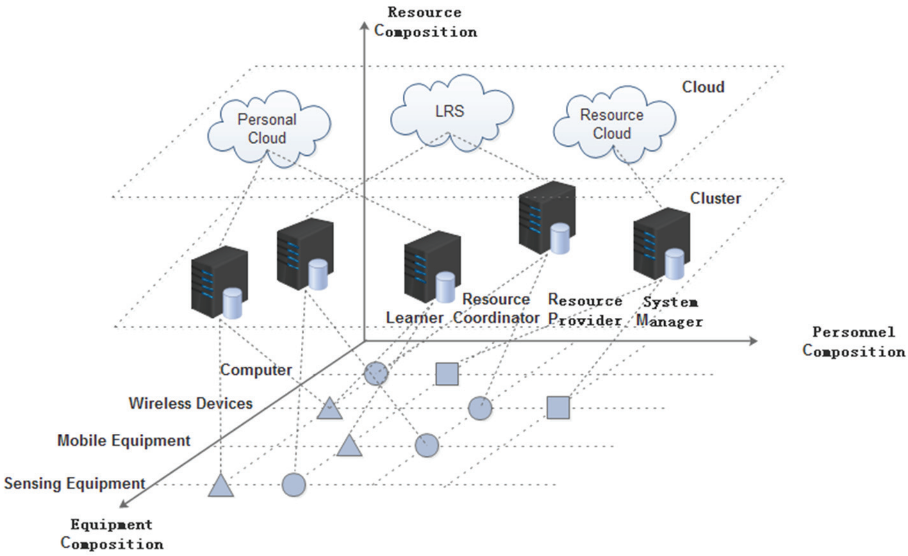

Fig. 1. The u-learning system structure model.

4. Learning Record Model Based on Experience API

4.1 Learning Record Model Based on Experience API

The main components of learning record model based on Experience API include: (A) learning record system, (B) activity agent, (C) statement, (D) authentication. Information interaction process of the learning record model is shown in Fig. 2. After accessing the Internet and being authenticated by the system, learners learn through web pages, LMS or applications. The e-learning resources generally include online courses, articles, web pages, instructional games, etc. Learners gain learning experience by browsing online learning resources and uploading them to the LRS through protocols and specifications of Experience API [8]. Specifically, the transfer process is: the activity provider defines the learning activities that the learner is engaged in and divides the activities into different groups according to the modules. The activity generates statements which are stored in LRS through the statement API of Experience API. The Experience API consists of four interfaces: Statement API, State API, Activity Profile API, and Agent Profile API. The Statement API is responsible for the storage and deletion of statements in LRS. The State API saves the activities in use to the buffer cache. The Activity Profile API can refer to the full description of activities stored in LRS; and the Agent Profile API adds proxy-related data to LRS.

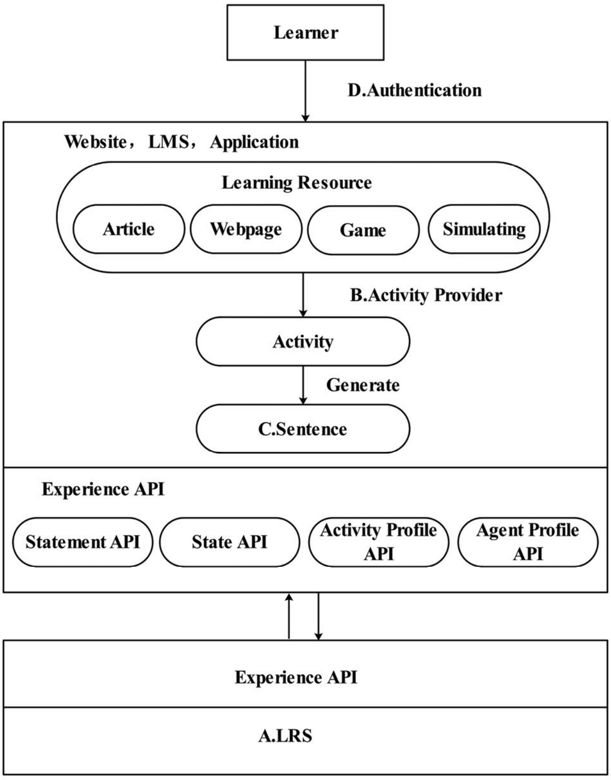

Fig. 2. Learning record model of Experience API.

4.2 Learning Record Information Interaction Process

Learners acquire learning experience through websites, LMS, applications or other learning terminals. The learning record information interacts with LRS to complete the information storage or retrieval. The specific process is: learners acquire learning experiences by entering web pages, courseware in LMS or application programs. The system transforms the learning experience into activity and generates sentences by activities. The statement stores or extracts information through the interaction between statement API in Experience API and LRS. The interaction between LRS and LMS is different from that of LRS. In LMS, LRS storage and access to learning records, and content package, release and output are completed in LMS. The information data recorded in LRS can be transmitted between independent LRS through report tools. It can also be transmitted to the LRS in LMS through the LMS internal report tool.

5. U-Learning System Architecture

5.1 Ubiquitous System Logic Architecture

Learning behavior inside and outside the system can both be recorded if the u-learning system is compatible with the Experience API. After integrating LRS into u-learning system, the function of learning system will become more powerful. Traditional u-learning system cannot track informal learning. If the u-learning system is reconstructed, the Experience API and the u-learning system are integrated, then the semantic relationship between verbs and activities in the Experience API can be used to record and analyze the data, which will provide better personalized learning experience for learners. The reconfiguration of the existing u-learning system is to establish LRS and Experience API related mechanisms of Experience API within the system. The synchronization between the LRS inside the system and the public LRS is achieved. In this way, the cloud storage of learning records is realized. The system architecture is shown in Fig. 3.

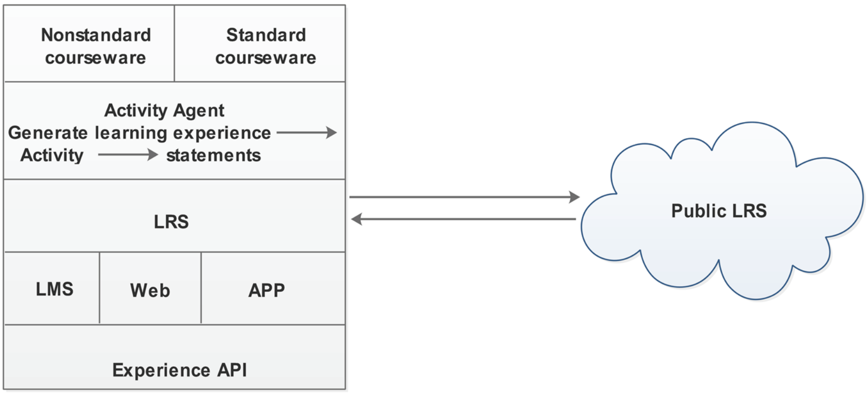

Fig. 3. Architecture of learning record tracking system.

5.2 Ubiquitous System Physics Architecture

The u-learning system mainly includes four parts: LMS, LRS, storage module, and u-learning activity module. The core modules of the system are LMS and LRS. LMS module includes mobile app and web application, which have the same function. LMS mainly includes course management module, course selection module, user management module, knowledge point management module, learning analysis module, course testing module, data report module, and question answering module. The course management module is able to create courses, upload course packages, edit courses and delete courses. The uploaded course packages are required to conform to the xAPI standard. The main function of knowledge point management module is to parse the knowledge points of the course package and store the knowledge points information into the system database. The learning analysis module can track, record and analyze the learners' learning situation. The data report module can generate visual charts of students' learning situation. In the question answering module, both teachers and students can initiate topics for discussion. LRS module mainly records students' learning records, including data retrieval, data management, data sharing and user management modules. Learning records stored in LRS are standardized data, so the data in this system can share data with other LRS and LRS clouds. Storage module mainly consists of system database and learning object library. In order to share learning resources with other LMS, learning objects are stored independently in this system [9]. U-learning activity module mainly refers to the use of third-party tools for learning. This system can obtain the learning records of these learners and store them in LRS (Fig. 4).

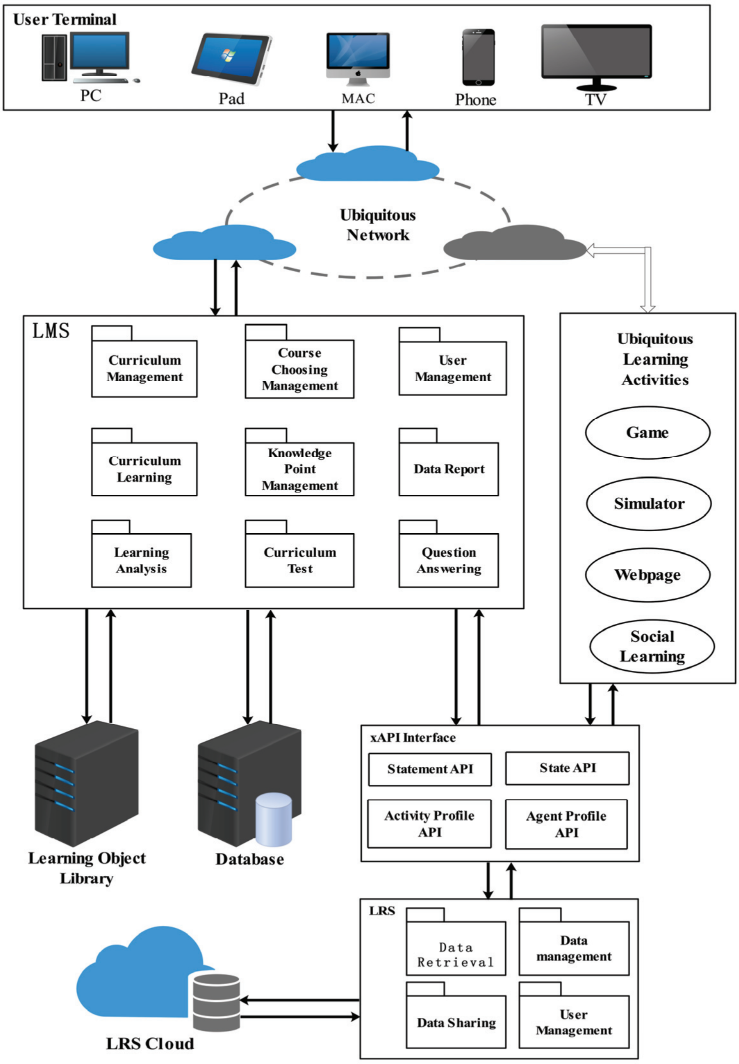

Fig. 4. Ubiquitous system physics architecture.

6. Learning Record Information Interaction Process

6.1 Classification of Knowledge Points

In this study, in order to track and record learners' learning progress more accurately, learning content is divided into several knowledge points in LMS. The division of knowledge points is based on the concept of learning objects and conforms to SCORM standard, which is fully compatible with Experience

API. Learning object is a new type of CAI (Computer Assisted Instruction) component based on the combination of object-oriented computer technology and related teaching theory [10]. Typical learning objects include various multimedia teaching contents, teaching objectives, teaching software and tools, etc. [11]. It is a learning resource organization form that can be used and reused in different teaching systems, including computer-based training system, interactive learning environment and intelligent computer-aided teaching system. In SCORM standard, Asset is the smallest unit of learning resources, and SCO can be composed of several Assets, which are combined according to certain learning objectives. SCO is the most basic unit of teaching resources editing [12]. A small SCO can be just a picture or a whole course. According to the course requirements, SCO can be chapters, sections, topics, units in the learning content, or units of any size. It is emphasized here that SCO should contain at least one learning goal, and it is a unit that can be recorded. In this study, the minimum granularity of SCO is a web page. Each SCO has relatively complete practical teaching meaning.

6.2 How to Transfer Learning Record to LRS

After the learner completes the learning resources, the learning record tracking system automatically generates data reports and transmits them to LRS. Statement is the core of Experience API. It has a very simple syntax structure. It uses the form of "actor + verb + object" to describe learning activities. All learning activities are described and stored in this form, such as "Xiao Ming (actor) completes (verb) exercises of CET-4 (object)" [13]. No matter what language is used to compile, this description is stable and universal. To ensure that the distributed nature of the Experience API remains unchanged, the logical structure of the statement is unchanged, but the active content of the statement is changeable. In addition to the structure of "actor + verb + object" mentioned above, statements can also include situational information, such as "Xiaofeng completed company induction training with a result of 85% on 21st Feb 2012 at 14:35". This approach ensures all the functionality of SCORM implemented through the Experience API and provides a more flexible structure. In a statement, the order of attributes is variable, and the format of statements can be JSON or XML. In the u-learning system, the process of uploading learning records to LRS is as follows:

1. To obtain the LRS username and password and access permissions.
2. The u-learning system gets the values of username, password.
3. Get operation is performed in Action and responds. Verb and Act can be selected through LanguageMap() and Verb is obtained from http://adlnet.gov/expapi/verbs/.
4. The object is transformed into JSON node by toJson() method and the string is converted to JSON.
5. The content of the active record is transformed into a formatted state via the SaveStatement() method and transmitted to LRS.

6.3 How to Read Learning Records from LRS

LRS allows authorization systems to retrieve learning records of learner in LRS, and we can use third-party reporting and data analysis tools to present learning records. So how do we get learning records from LRS? We'll use the GET statement in the Experience API, which provides many parameters to filter the returned statement set. We can filter not only the actor, verb, and object of the statement, but also the part based on the statement context, or limit the result to a certain period of time. We can use the Get statement to ask similar questions: “Who has completed ‘Fractional multiplication’ since yesterday?” and “What has happened in a certain context of ‘Science’ since last month?” [14]. The learning record display effect in u-learning system is shown in Fig. 5.

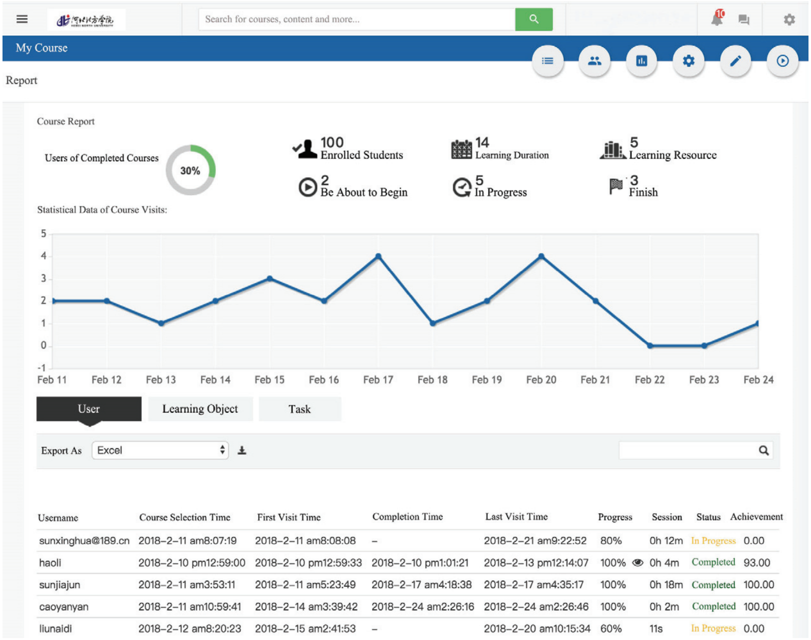

Fig. 5. Learning record display effect.

7. Analysis of Learning Activities and Push of Learning

In LRS, learning record information is stored, which includes learners, learning content, learning achievement, learning time and learning environment, etc. The u-learning system can acquire information and make horizontal and vertical analysis of these learning records. Through the analysis, we can know which knowledge points students spend more time on and which knowledge points they are interested in [15]. Teachers can adjust and improve their teaching methods according to the analysis results. Pushing the analysis results to the students, the students adjust their learning behavior according to the results. These ways can help improve the learning interest and quality of the learners.

In the learning process, the time for learning each knowledge point is set to t_i, among which $i \in (1,n)$. It is roughly thought that learner’s learning of knowledge points is divided into first learning and review. We use t_{ij} to indicate the time when the learner review of the i knowledge point for the j time. Then we can analyze students’ learning behavior from two aspects: horizontal and vertical. Horizontal analysis refers to the analysis of the learning time of lots of learners and the induction of important knowledge points. Vertical analysis is the comparison and analysis of the learning time of the individual. Therefore, it can infer the important knowledge point for the individual in the whole process of learning.

We have a simple definition for the important knowledge point mentioned above. If a learner spends more time on a knowledge point, or spends more time on review, or likes and collection operation on this knowledge point, we think that the learner is more interested in this knowledge point or the knowledge point is an incomprehensible point. For such knowledge point, it is known as an important knowledge point.

7.1 Vertical Analysis of Learners Learning

In the case of ignoring learning scenarios, learners learn content blocks containing n knowledge points. f_i is used to represent learners' learning time on i knowledge points, as shown in formula (1).

$$f_i = \frac{t_i}{\sum_{i-1}^{n} t_i} + c_i + \frac{\sum_{j=1}^{p} t_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{p} t_{ij}}, i \in (1, n), j \in (1, p) \tag{1}$$

Among them, t_i represents the learning time for i knowledge points, and t_{ij} indicates the time for j review of the i knowledge point. c_i is a Boolean value. When $c_i = 1$, it means that learners have been collected i knowledge points. When $c_i = 0$, there is no collection operation. We analyze and compare the value of f_i on each knowledge point, and deduce the key knowledge points for learners, so as to follow-up study.

7.2 Horizontal Analysis of Learners' Learning

In the course of teaching, teachers or other educators need to carry out a comprehensive study, analysis of all the learners and find out the suitable learning method for most of the learners. Among the numerous learners, we analyze their different knowledge points, figure out the average time, find out the key knowledge points, and learning time pay special attention to improve the learning efficiency of learners. The horizontal analysis process is shown in Fig. 6.

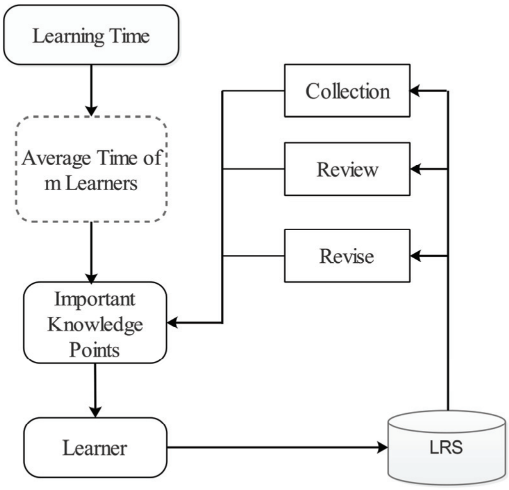

Fig. 6. Analysis process of key knowledge points.

Firstly, we figure out the average time used by m learners when they learn i knowledge points. The average time is expressed in T_i, as shown in formula (2).

$$T_i = \frac{\sum_{k=1}^{m} \mathrm{t}_{ik}}{m}, i \in (1,n), k \in (1,m) \tag{2}$$

Different people have different understanding for a knowledge point, and the degree of subjective difficulty is different. Therefore, in addition to the average value of learning time, the average value of the collection operation is also expressed, as shown in formula (3).

$$C_i = \frac{\sum_{k=1}^{m} c_{ik}}{m}, i \in (1,n), k \in (1,m) \tag{3}$$

Similarly, the c_{ik} is also a Boolean value, which indicates whether the learners have collected the i knowledge points. In the learning process, the learning ability of m learners is different, and the learning speed of a knowledge point is different, so the difference in progress will be produced when the learner is learning. Slower learners tend to lag behind other faster learners in understanding and mastery, so they will take the way of review to strengthen mastering and understanding of the knowledge points. Here, the average value of review time is also used to represent the review time of the i knowledge points, as shown in formula (4).

$$t_i = \frac{\sum_{k=1}^{m} \sum_{j=1}^{p} t_{ik}}{m}, k \in (1,m) \tag{4}$$

Among them, p represents the number of reviews, which is an uncertain value, depending on different learners and different knowledge points. t_i represents the average time that m learners spend looking back the i knowledge point. t_{kj} is the time that $No.k$ learner spends reviewing the knowledge point for j times. We sum up all the review times of i knowledge points. It is used to indicate the total value of review time, so that the average value can be calculated again. F_i indicates the learning time for this knowledge point that can be calculated by the following formula, as shown in formula (5).

$$F_i = \frac{T_i}{\sum_{i-1}^{n} T_i} + c_i + \frac{t_i}{\sum_{i=1}^{n} t_i}, i \in (1,n) \tag{5}$$

Each knowledge point has a time measure. We sort them by their size so as to get important knowledge points. Because LRS stores all learners' learning records, it is more meaningful to calculate the key knowledge points by this way. But these knowledge points are not applicable to every learner, but it can provide a reference for educators in the teaching process.

7.3 Analysis of Learning Behavior

In the u-learning system, there are tens of thousands or even more users. Every day, they do a lot of operation such as logon, question and answer. Each user's operation will be stored in LRS in xAPI format. We may make statistics and analyses on learning data. We may analyze the behavior of users and get the main way of accessing u-learning system, as shown in Fig. 7. For example, we can analyze the degree of user activity, as shown in Fig. 8. We provide personalized learning suggestions for learners by analyzing users' learning behavior and vitality.

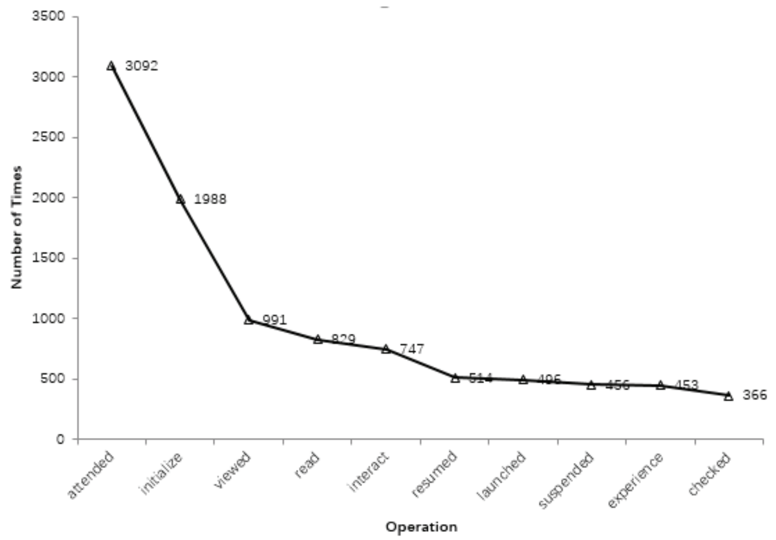

Fig. 7. Analysis of learning behavior.

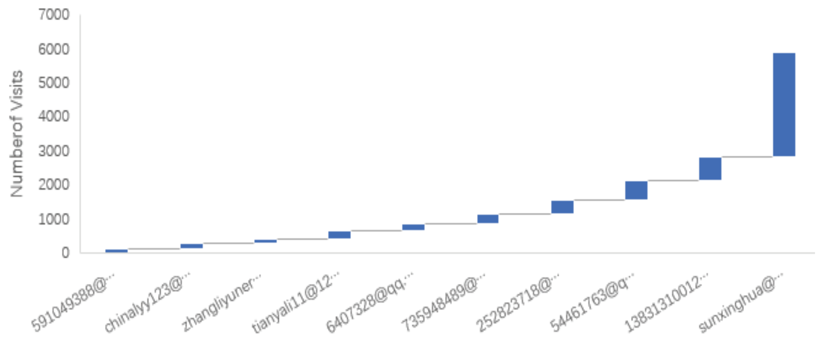

Fig. 8. Learning behavior analysis.

7.4 Personalized Learning Resources and Recommendation Push

After the analysis of students' learning records, the system also pushes learning suggestions and personalized learning resources to students according to the analysis results. This system adopts three push strategies, including platform push strategy, teacher recommendation strategy and student customization strategy [16]. The push process is shown in Fig. 9. Platform push is mainly based on the system's vertical analysis of users' learning. The results of individual learning analysis are pushed to learners, and learners adjust their learning strategies according to the results. Teacher push is mainly based on the horizontal analysis of user learning. Teachers can choose appropriate learning resources to push to learners according to the analysis results. Student customization means that learners choose their own learning resources according to their interests and the information they receive. Through these three push modes, learners' interest in learning and learning quality can be effectively improved.

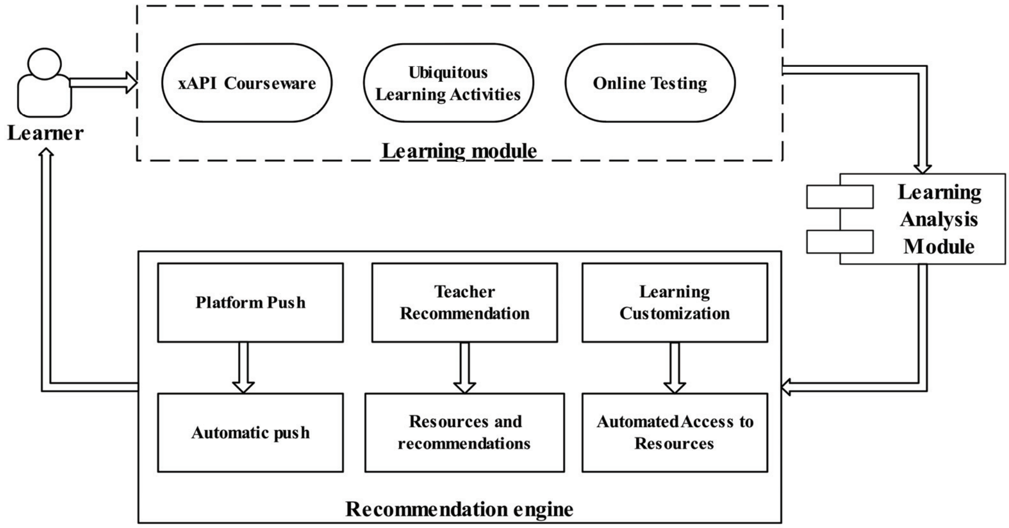

Fig. 9. Personalized learning recommendation model.

8. Results and Discussion

8.1 Results

After the development of the u-learning system, the system has been put into trial run online in Hebei North University. We selected about 150 students from four classes to learn through the u-learning system. After running the u-learning system for one year, the user experiences were collected from the users in the form of questionnaires. We sent out 150 questionnaires and collected effective feedback from 118 users. The results of the questionnaire show that 86% of users are satisfied with the push of learning platform, and 79% of users believe that the learning platform can increase the learning interest of learners, and 80% of users believe that the platform can improve the learning quality of students. The results are shown in Figs. 10–12.

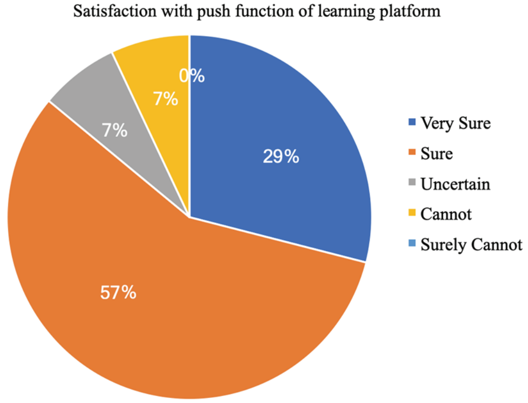

Fig. 10. Satisfaction of push function of learning platform.

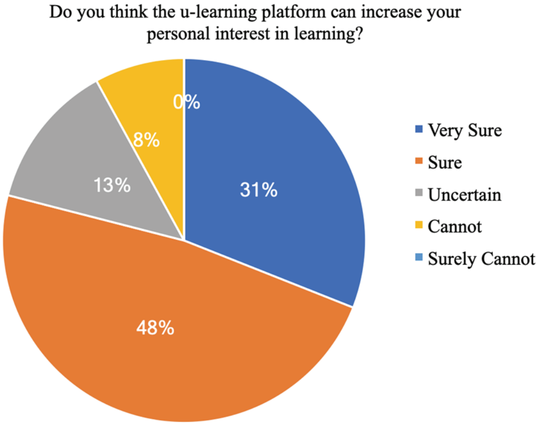

Fig. 11. Satisfaction of learning platform increases individual learning interest.

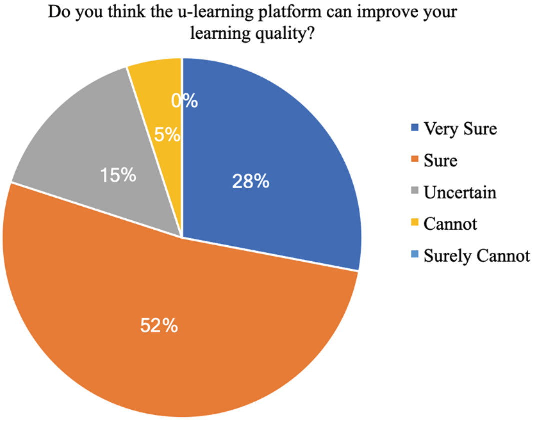

Fig. 12. Satisfaction of learning platform improves individual learning quality.

8.2 Discussion

Since the release of Experience API, many scholars have carried out studies on Experience API, some of which are listed as follows. Chakravarthy and Raman [17] discussed the possibilities of "Educational Data Mining on Learning Management Systems Using Experience API". Papadokostaki et al. [18] presented an innovative implementation of an adaptive LMS-free learning system with the use of xAPI. Glahn [19] analyzed how the concepts of the Experiences API were integrated in a mobile learning application and how the app used learning analytics functions based on the collected data for informing the learners about their learning performance, for encouraging them to actively use the app, and for orchestrating and sequencing the learning resources. Kevan and Ryan [20] summarized major educational research opportunities and key challenges to implementation. Hamzah et al. [21] explored the Tin Can API for web usage mining in e-learning applications on the social network.

In these studies, there are no related research on u-learning system based on Experience API. The study of this topic fills the gap in this respect, and has certain reference for those engaged in the relevant research of Experience API.

9. Conclusions

Experience API is a new online learning specification, and its emergence has changed the existing learning models based on information technology. First of all, Experience API makes up for the shortcomings of SCORM, so that learners' learning is not limited to browser-based learning. Secondly, it can track and record almost all kinds of learning activities. In this paper, a u-learning system architecture based on Experience API is proposed and implemented. This system integrates Experience API and realizes the storage and acquisition of learning records based on LRS, which can provide learning records to learners completely and accurately. This paper also constructs a learning record model based on Experience API in horizontal and vertical perspectives, and analyzes learners' learning behaviors and activities in ubiquitous learning system. Through the analysis, it is found that the proposed u-learning system can greatly improve learners' learning interest and quality. In the future, we will carry out theoretical research and implementation on learner profile, content proxy, protocol, capability authentication and so on. We will gradually improve the learning record tracking mechanism based on Experience API in ubiquitous learning system.

Acknowledgement

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