DEVELOPMENT OF
UBIQUITOUS SMART LEARNING SPACE BASED ON STAKEHOLDERS: A CASE STUDY

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ABSTRACT

To enhance learning validity by reconstructing traditional learning space to be ubiquitous smart learning space under the background of smart education and the COVID-19 pandemic. There are 4 objectives in the thesis, 1) to find the stakeholder interests in the ubiquitous smart learning space. 2) to construct the ubiquitous smart learning space, 3) to find user's satisfaction. 4) to find the effectiveness of ubiquitous smart learning space. To find the core stakeholder's interests, the author surveyed 477 students and 476 were valid from 28 majors with Likert 5-point questionnaire; interviewed 5 managers and 10 professors with over 10 years continuous work experience. Based on the result analysis, the research proposed the core stakeholder model of the ubiquitous smart learning community concept model, their interest modal is the "SMART" learning environment model. To construct it, with "Zhongtai" technology and software engineering method, the research gave its architectural model, function and components UML diagrams and implement interfaces. Ubiquitous smart learning space can support various learning, the research illustrated independent learning, collaborative learning, immerse learning model, creative learning model and critical thinking learning model in it. To test learning environment sanctification, the research introduced 5 learning models worked in the learning space and surveyed 275students and interviewed 10 teachers with Likert 5-point instrument. At last, the research experimented 64 students for 20 weeks on critical thinking and collaborative learning skills improvement with standard questionnaires, the compared t-test results showed that ubiquitous smart learning space has significantly efficiency on critical thinking and collaborative learning.

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Lei Song

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CHAPTER 1

INTRODUCTION

1.1 Background

1.1.1 Educational Change and Main Problems Facing the Development of Smart Education

The change of social types and the development of media technology have always been the fundamental force to promote educational reform. Looking back on the development of education, whether spoken language, text, electronic simulation technology, multimedia network interaction technology, the emergence of each technology form has triggered a revolutionary change in human education. At present, human beings are standing at the forefront of the fourth Industrial Revolution. Intelligent information technology, represented by artificial intelligence, big data, and blockchain and so on, is triggering a new round of educational reform which is called smart education. The emergence of smart education came from the 2008 speech "smart earth: the next generation's leadership agenda" (Zhang, 2010) by IBM president and chief executive officer Mingsheng Peng in the New York City foreign relations committee. Soon after, under the guidance of the concept of smart earth, smart education broke out and became the advanced stage and future direction of education development in the information age.

China's Ministry of Education's "Education Informatization 2.0 Action Plan" marked China's education informatization into a new era of development and marked the smart education from 1.0 to 2.0 era. Smart education will no longer be limited to a few developed provinces and cities at the initial exploration; it will be strategically promoted and implemented (Zhang, 2018) across the whole country. For the realization of this goal, it needs to solve many problems (Zhang, Tao, 2018) during developing smart education.

(1) Large-scale individualized education. The realization of individualized education is a beautiful ideal and universal pursuit of future education after the popularization of education. But it is limited by China's huge student scale, and the educational technology application has not been effectively brought into play. It is difficult to realize individual learning according to each student's needs and preferences.

(2) Precision management of education and teaching. To respond to and demonstrate the digital governance capabilities, various educational institutions have purchased many business systems, but because the systems come from different businesses, the data interfaces between the business systems are not connected and the data cannot be read online in real time. Big data' 4V（Volume, Velocity, Variety, Value characteristics are not obvious in the process of teaching and students' learning effect still depends on the experience to a great extent, and the improvement of teaching lacks scientific data analysis. In the process of education management, managers often heavily rely on experience with excel, word document, which is difficult to make accurate control and management of the educational process.

(3) Deficient training of critical thinking ability. The traditional talent training model and talent evaluation mechanism emphasize knowledge over ability, teaching is more to help students understand and master book knowledge, resulting in students' general examination-oriented ability, which cannot meet the demand to critical thinking

cultivating.

(4) Balance development of the quality of education. Because of the unbalanced economic and social development in various regions, there are great differences in the level of education development between urban and rural areas, between developed and developing countries. In recent years, although efforts have been made to narrow the gap by information technology, the problem has not been fundamentally solved, more parent demand for Xuequfang, literally school district houses, as the country's education authorities require that public schools enroll pupils from designated areas, propelling prices.

(5) Learning space, breaking through the framework of formal schools, should include all stages and forms of the educational system to formulate a lifelong learning society. From March 1971 to April 1972, the members of the International Education Development Committee visited a total of 23 countries belonging to the first world, the second world, and the third world, then they personally visited a total of 13 international and regional organizations. The cultural organization headquarters held 6 administrative meetings. Finally, on May18, 1972, the Four Representative Committee submitted to the Director-General a report written by all members, namely "Learning to Survive-Educational World Today and Tomorrow" (World of Education Today and Tomorrow, also referred to as "Learning to Survive", wrote that the education of limited time (prescribed for the school age period) and limited space (must be in the school) must be abolished. School education should be abolished. Education should not see as the end of education; it should be regarded as a basic part of the entire educational activities. Educational activities include both institutionalized school education and extra-school education.

Life-long education includes all people, regardless of gender, age, difference between rich and poor, race and gender. The UNESCO Hamburg education researcher Dabe proposed that lifelong education has the characteristics of democratization and opposes educational knowledge serving the elite, which is equal access to education for the public with various abilities. General Secretary Xi Jinping, President of China, emphasized: In response to the development of information technology, promote educational reform and innovation, build a networked, digital, personalized, and lifelong education system, and build a learning society for everyone, learning everywhere, and learning all the time. A learning society, training many innovative talents is a major issue mankind facing. The rapid development of information technology not only profoundly affects and changes people's production and lifestyles, but also provides a new way to build an education system that serves lifelong learning for all people. In the new era, we must make full use of information technology, accelerate the development of a more open and flexible education system suitable for everyone, and build a learning society.

(6) Lack of systematic and sustained smart learning space construction (Zhang, Tao, 2018). The lack of specialized research and management institutions leads to fewer systematic solutions and applied research, most application are individual terminal products; the lack of uniform construction standards and technical specifications leads to the difficulty of compatibility between systems and products, the difficulty of giving full play to the advantages of the system, and the obstacles to the development and application of smart education are: 1) the lack of an effective platform for cooperation in political, industrial, academic and research roles, and 2) the difficulty of integrating superior resources; 3) most of the existing products and technologies are transformed and applied by enterprises on the basis of their own existing technologies, lack of innovation and core achievements incubation platform and base, so new technology and new design are difficult to effectively transform into educational services; 4) the

complete and healthy industrial chain has not yet been formed, so it is difficult to realize the sustainable development of smart education industry.

1.1.2 Problems for Using Learning Space in the COVID-19 Epidemic

Online teaching caused by the epidemic situation of COVID-19 is spreading out in colleges and universities all over the world. Online teaching is changing teachers' teaching methods and students learning methods, that is, learning from physical environment transfer to non-physical environment. With large-scale practice, the following common problems are found in China.

(1) Advanced educational technologies lack highly adaptive concepts and space support （Liao, 2021).

The sudden outbreak epidemic accelerated the practice of educational theory. In fact, in China, before the epidemic, the traditional physics classroom teaching habits are still used to build online teaching. This idea and habit cannot accept many advanced teaching technologies, it leads to the slow innovation and application of technology in education compared with other industries. After the later epidemic stage, the willingness of schools to continue use educational technology is reduced, which is not conducive to the development of educational technology. The application of educational technology lags, as there is no effective new learning space to support the integration and application of educational technology, and there is no advanced educational concept to support the continuous construction of educational technology in smart learning space. It leads to the adaptability of educational technology and learning efficiency decline.

(2) Conflict between teaching space and teaching habit (Zheng, 2018).

In addition to the influence of applicable places on educational technology, the main reason of influencing smart teaching is the teacher's teaching inertia or educational memory. This inertia and memory have been patterned and solidified and has entered collective unconscious state. This kind of memory naturally achieves tacit understanding psychological field in the process of teachers' interaction with the surrounding teaching environment. There is no doubt that the use of a new technology, to some extent, will change the original teaching habits and even behavior habits, breaking through many years to form a psychological field. Especially with the elder teachers and managers have an inexplicable sense of fear and rejection of new technologies. It is necessary for teachers and managers to change their teaching and management habits hastily and reconstruct the present online learning space to support teachers and managers to adapt to the new technology quickly. The information technology acceptance strategy of learning space is the precondition for the successful construction of learning space, which will affect the scope of use of advanced educational technology and the validity of new learning space.

(3) Inadequate security of educational technology and learning services（Liao. 2021).

This kind of sudden large-scale online teaching activity has put forward the most rigid test for the service ability, such as the shortage of online resources, co-construction supporting, technology support using, the lack of data security supports, and process support for learning (such as academic seminars, competitions, and book resources) and follow-up services (such as internships, employment) and student innovation services and social integration support. Under the background COVID-19 and in the future educational reform, to promote effective learning behavior firstly need to promote the core stakeholder to form a community of interests, and allow each role in the collection to participate, build and gain core benefits to increase their internal drive, and continue to support the co-construction of learning space. Therefore, the author conducted a questionnaire on function design for learning managers and service providers to allow

they can use the space jointly provide the necessary management and timely services for students, which is helpful to improving learning efficiency.

1.2 Research Questions

According to the general goal and the feasibility requirement of reconstruction project, the research questions of this study are as follows:

1) Is it necessary to construct the ubiquitous smart learning space and who are the stakeholders and what are their core interests to enhance collaboration and critical thinking ability?

2) What elements should be included in a ubiquitous smart learning space?

3) What are users' level satisfaction on ubiquitous smart learning space?

4) Can the ubiquitous smart learning space improve the leaners' collaboration and critical thinking ability?

1.3 Research Objectives

By innovating learning concept and educational technology method to enhance the learning space and improve the learning validity under the background of smart education and the COVID-19 pandemic. The objectives include:

1) to study the stakeholder' interests in the ubiquitous smart learning space to enhance collaborative ability and critical thinking.

2) to construct the ubiquitous smart learning space.

3) to study user's satisfaction on its ubiquitous smart environment.

4) to study collaborative ability and critical thinking of students learning with ubiquitous smart learning space.

1.4 Research Hypothesis

According to the research objectives, the study assumes following:

The students who study through the ubiquitous smart learning space receive higher posttest scores on collaboration and critical thinking than pretest scores.

1.5 Research Scopes

This study includes 4 phrases:

（1）Phrase 1 on study need analysis & solution factors analysis: to study the problem background, education change trends and theory of smart learning, smart learning space framework and projects, and provide standards for the construction of ubiquitous smart learning space. This research is not main study question, but it is the precondition of the main, so it is necessary to do it around objective.

1) Need analysis

Subject: literature content of education change trends, smart education, smart learning, and learning feature needs change

2) Solution principle compares

Subject: learning space evolution framework and implement project's introduction

3) Virtual learning space acceptance factors analysis

Subject: Technology adoption evolution models in online education

（2）Phrase 2: Function needs analysis in model design, to survey the stakeholders and core interests in the smart learning space.

Subject: Data analysis of core functional requirements includes two forms:

questionnaires and in-depth interviews. The subjects of the survey or interview are three groups of learning-related stakeholders, namely managers, teachers, and students. For students, I selected 477 students with online learning background as sample; 5 managers and teacher should have the work content of the managers are covering educational administration management, student management and administrative management, and have more than 5 years of continuous work experience. The selection criteria for 10 teachers who have participated in the MOOC project and the open class project of the online education platform.

Data: The survey questionnaires (Appendix 1) distributed on 477 copies randomly Alibaba data collection platform and 476 copies are valid. Interview (Appendix 2) organized in face to face with videos and records, records have been assured with interviewees. Use Excel and SPSS to measure average score and rank.

(3) Phrase 3: Design the ubiquitous smart learning framework, construct it and to find user's satisfaction on its ubiquitous smart environment.

Based on smart education, smart learning, and lifelong learning, to propose ubiquitous smart learning environment conceptual model.

Based on stakeholders and core interest survey, to propose stakeholders and their activities conceptual models.

Based on technology adoption evolution models (TAM Model with Ubiquitous Learning Characters), to choose key technology and make construction standard, principle, and architecture model.

Based on key technologies (Zhongtai, multi-experience development platform, interactive technology, big data, cloud computing and ubiquitous network), to implement the ubiquitous smart learning platform.

Based on relationship between learning environment, learning activity and learning efficiency, to design questionnaire and do users' satisfaction survey on its learning environment.

(4) Phrase 4: Learning efficiency experiments.

The independent variable in this research is ubiquitous smart learning space, variable (learning efficiency) with two categories: collaborative skill and critical thinking skill. The dependent variable is the posttest score. The posttest is made up of "Collaboration Obstacle Evaluation Form items and "Chinese version of critical thinking disposition inventory" items.

Subjects

The population for this study consisted of undergraduate students in industrial technology, enrolled at Southwest Forestry University, Kunming, China. The sample is made up of students enrolled in the 64 of Computer Science 2021. There are two sections, pretest and posttest on collaborative skill and critical thinking skill.

1.6 Research Framework and Conceptual Framework

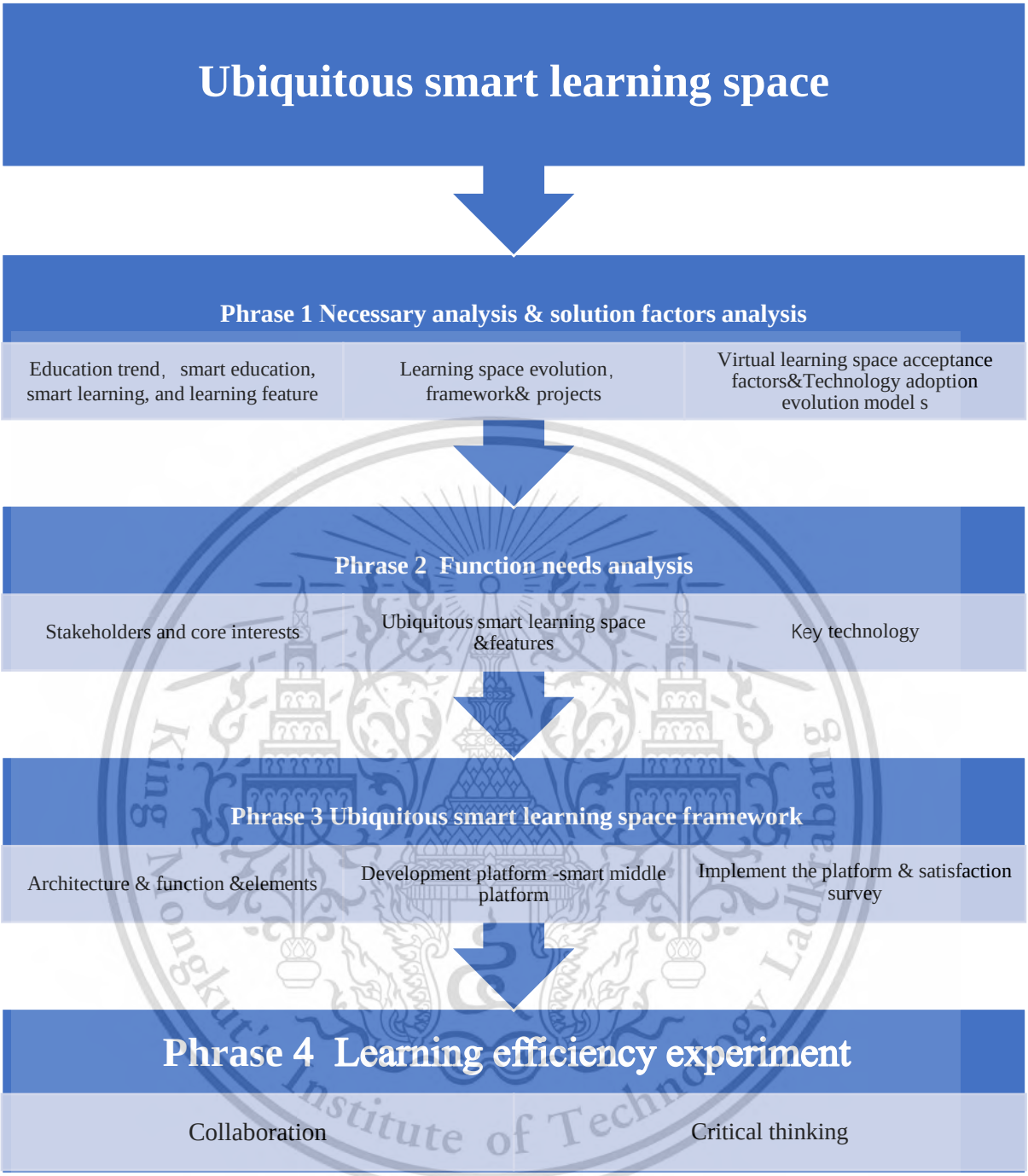

Figure 1.1 Research Framework

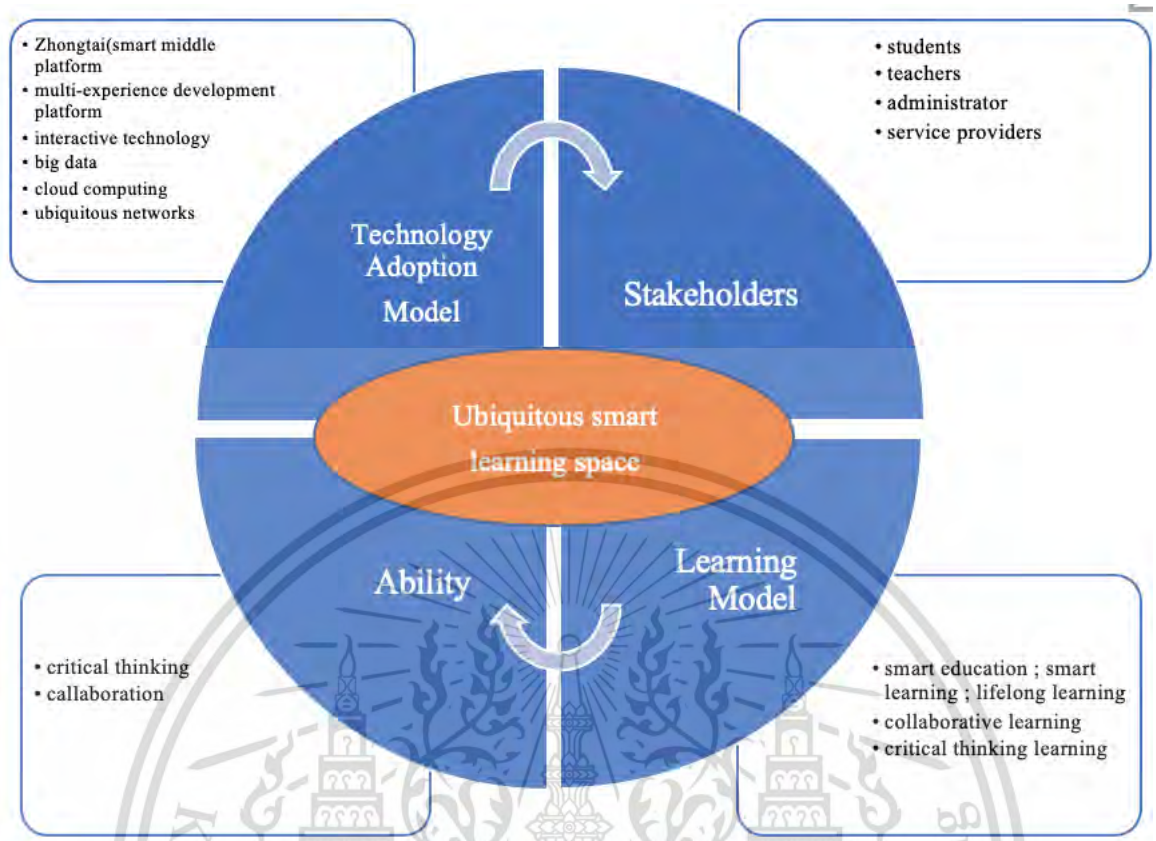

Figure 1.2 Conceptual Framework

1.7 Definition of Terms

(1) Ubiquitous Learning (U-Learning)：is a way that anyone can obtain any information they need anywhere and at any time. It is to use information technology to provide students with a 4A (Anyone, Anytime, Anywhere, Any-device) learning that can be used anywhere, anytime, and with the technological tools available at hand to carry out learning activities. Learning content includes formal education and informal education, which is a new trend after the development of e-learning, digital learning, and mobile learning.

(2) Smart Learning: smart learning is a learning process in which learners obtain learning resources in an intelligent environment, flexible learning activities, and rapid construction of knowledge networks and interpersonal networks. Smart learning aims to develop learner's learning intelligence and improve learners' innovative ability. As a new learning method developed based on digital learning, mobile learning, and ubiquitous learning under the guidance of the concept of smart education.

(3) Smart Learning Space：it can be understood as an intelligent learning system or platform, which cannot be separated from the support of intelligent learning environment and emphasizes the interaction between learning subject and environment. Intelligent learning environment refers to a learning place or activity space that can perceive learning situation, identify learners' characteristics, provide appropriate learning resources and convenient interactive tools, and automatically record learning process and evaluate learning results in order to promote learners' effective learning，

the difference between the smart learning environment and the general learning environment is that the design of the smart learning environment is to distinguish people's understanding, intelligence and ability and earning in an intelligent learning environment in which people can learn at anytime, anywhere, in any way and at any pace can support learners to learn easily, engaged and effectively (abbreviated as 3 E).

(4) Zhong-tai: Internet term, generally used in large enterprises. Generally, it refers to building a flexible and rapid structure to respond to changes, quickly realize the front-end requirements, avoid duplication construction, and achieve improving work efficiency. This is an upgrade and enhancement of the traditional platform and further solved the function boundary between platforms and data island problem that traditional platforms failed to solve.

(5) Ubiquitous smart learning space: is an open and smart learning environment based on ubiquitous network and cloud computing, supported by resource sharing, powered by a smart middle platform, and driven by collaborative interaction, integrating multiple stakeholders, and supporting learners to learn easily, engagingly, and effectively.

(6) Stakeholders: stakeholder refers to “any group or individual that can influence the realization of an organization’s goal or is affected by the goal”, here refers to teacher (educator), student, administrator, service provider .

(7) Collaborative ability: students work in groups toward a common academic goal, this method is all about teamwork and collaboration, students are active and interactive. Interaction and participation are necessary tools for the construction of knowledge where the activities involve the terms by, in, and for learning. It means learners have the freedom to listen, debate, understand, justify, and impart their views.

(8) Critical thinking: It is composed of Truth-Seeking, Open-Mindedness, Analyticity, Systematicity, Self-Confidence, Inquisitiveness, and Maturity.

CHAPTER 2

LITERATURE REVIEW

2.1 Trends in Learning Characteristics and Learning Style

2.1.1 Smart Education

(1) Human society has gone through three industrial revolutions, now it is now in the fourth Industrial Revolution. The term Industry 4.0 originated in the German government's high-tech strategic project to computerize manufacturing, considered the next stage (Zheng, 2018) as digital manufacturing with the deep network, green, intelligence 4 big characteristic. January 2016, the 46th World Economic Forum was held in Davos, Switzerland, the theme was control of the fourth industrial revolution, Among the many challenges around the world, how to shape the fourth Industrial Revolution is the most powerful challenge. With the advent of mobile networks, sensing technology and artificial intelligence and machine learning, the fourth industrial revolution, whether in terms of speed, scale, or impact, are far ahead of the three technological revolutions (Tian, 1996). In industry 4.0, integration, intelligence, innovation, integration and so on become the key words of social development, artificial intelligence, virtual reality, big data, block chain, 3D printing, and other information technologies have become the key force to push the society and education forward.

(2) Educational change in the industrial 4.0 era

Before discussing educational reform in the context of the fourth Industrial Revolution, it is necessary to review the development of education. There are two typical expositions or understandings on the development theory of education in academic circles: one is the four educational revolution theory based on the change of social form; the other is the six educational revolution theory based on technological innovation. From the point of view of social change, many scholars divide human society into four forms: primitive society, agricultural society, industrial society, and information society. According to this view, human society has experienced three educational revolutions and is now in the fourth educational revolution. The first educational revolution was marked by the emergence of words and schools; the second was marked by the invention of papermaking and printing; the third was marked by the emergence of class teaching system; the fourth educational revolution was marked by the information technology represented by computer and internet (Fig.2.1) (Tian, 1996), (Zheng, 2018)

From the perspective of technological innovation, educational reform is directly related to the revolution of information communication technology. The revolutionary of human information communication technology is as follows: spoken language (produced about 3.5 million years ago) → text (produced about 3500-3000 BC) → printing (produced about 7th century AD) → electronic simulation information technology (produced about late 19th century and early 20th century), multimedia network interaction technology (produced in 1990s), now is currently in the revolution marked by intelligent information technologies such as cloud computing, big data, the Internet of things, and virtual reality.

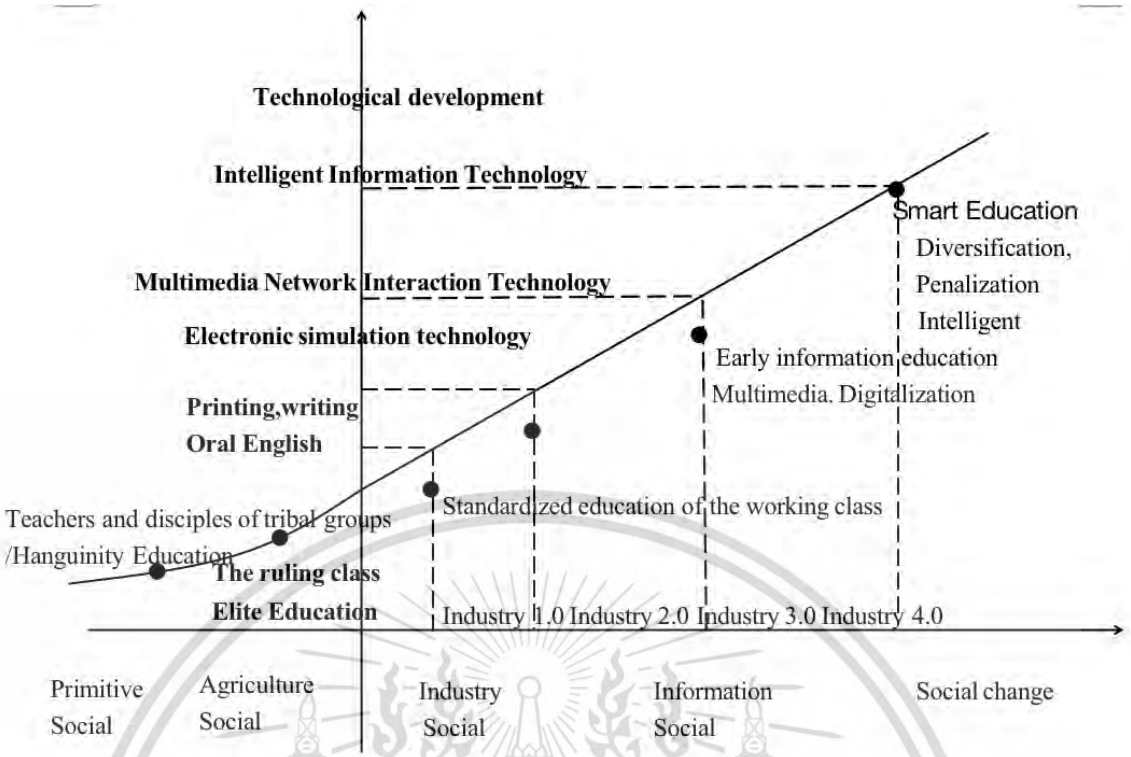

Figure 2.1 Trends in Technology, Social and Educational Change

Therefore, based on these revolutionary processes, some experts and scholars divide human education into six educational revolutions.

In fact, the development and transformation of education are closely related to the change of social formation and the development of media technology (shown in Fig. 1), they promote each other and promote the continuous development of education. By 1769, British James Watt improved the steam engine, promoted the era of mechanized production, social form from agricultural society into industrial society (industry1.0). By 1870, the breakthrough and application of electric energy, the emergence of internal combustion engine, the division of labor and the realization of mass production opened the prelude of the second industrial revolution. In industrial 1.0 and 2.0, to meet the needs of mass production, standardized education with the main form of class teaching has become the mainstream. Its main task was to transport many qualified industrial workers for the industrial production line. Into the information age, the invention, popularization and application of computer and electronic information technology set off the third industrial revolution, multimedia teaching, computer aided teaching, digital resources and so on began to appear. Now, intelligent information technology, represented by big data, artificial intelligence, block chain and so on, is leading us into the industrial 4.0 era, The use of technology in education is becoming the norm, educational reform has been laid a profound brand of the times. Under this background, smart education with the diversification, individuation，intelligence, ubiquitous learning space has become the main form of future education(shown in figures 2.2 and 2.3).

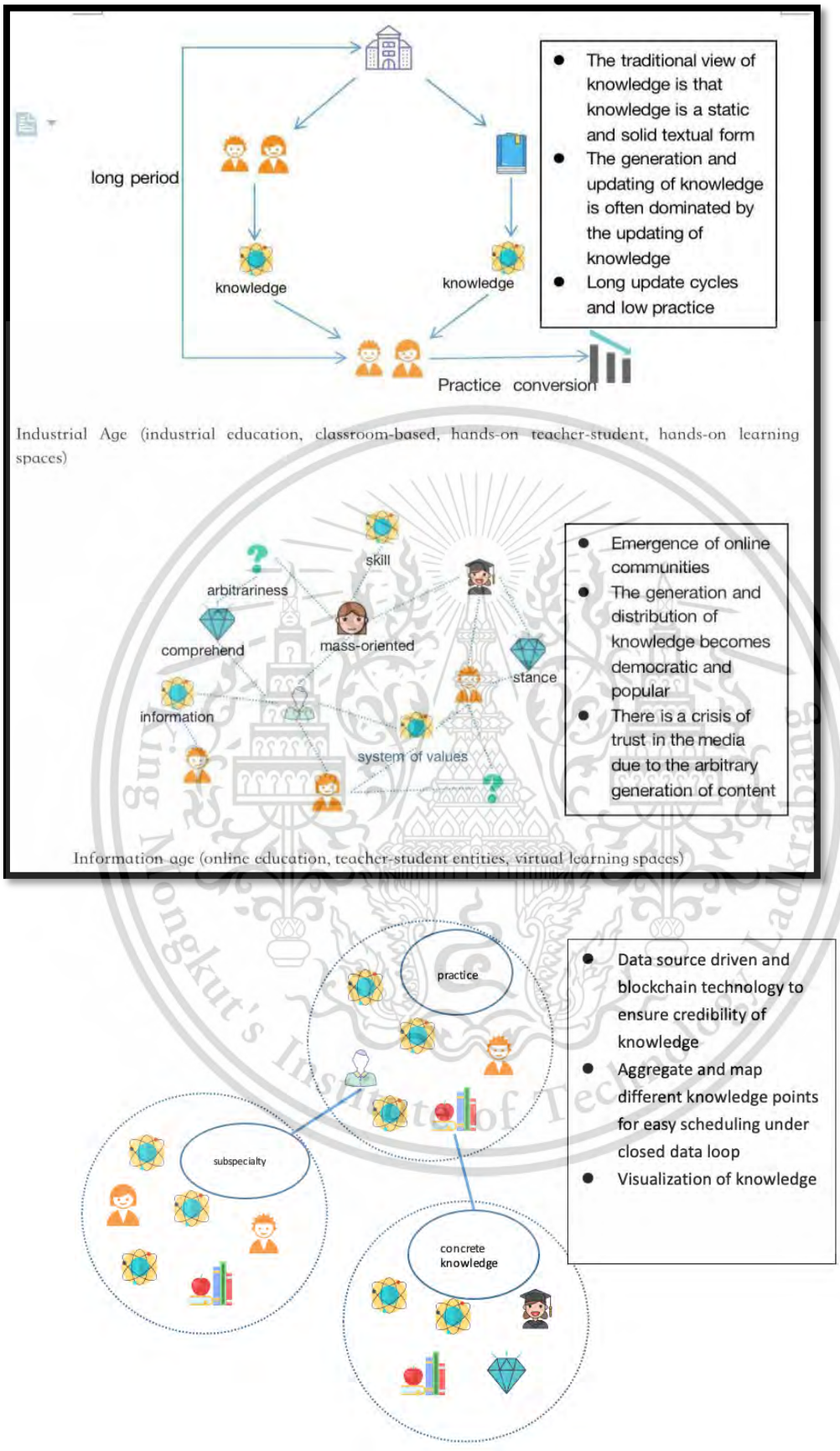

Figure 2.2 Changes in Learning Characteristics of Different Times

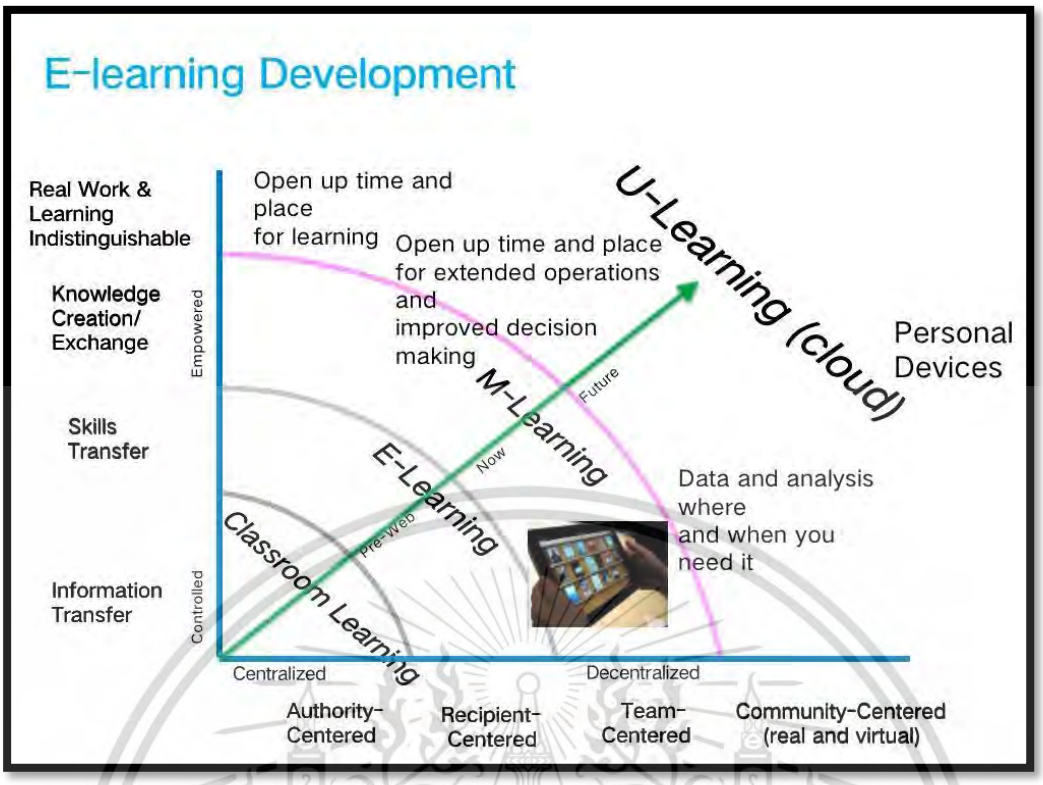

Figure 2.3 Trends in Learning Patterns

2.2 Development Status of Learning Space

2.2.1 Different from Teaching Space Construction

(1) Before learning space, people usually use teaching space to refer to this kind of place, and the place with teaching activity. Characteristics of teaching space in material form include size, shape, closed or open space, flexibility of space adjustment, combination and so on. Most typical teaching space is traditional classroom, and with the characteristics of podium in front, determinant table and chair layout, clear front, and back direction, and are mainly used to carry out face-to-face teaching activities. The rise of learning space is closely related to the change of people's understanding of learning process, the wide application of computer network communication technology in the field of education, and the attention paid to informal learning. The evolution from teaching space to learning space is not a simple concept replacement, both of which contain rich metaphors. This paper will analyze the teaching space and learning space from the perspective of comparison to reveal its rich connotation. (1) Learning space implies that learning is not limited to school classes, it can occur in any place. Therefore, the learning space is not limited to the classroom, teaching laboratory and other teaching space, it also covers the learning space inside and outside the campus, and even covers the formal and informal learning space. This change reflects the researchers' attention to the learning activities that occur outside the classroom. The scope of teaching space is mainly limited to the classroom, teaching laboratory, computer room and other places used to carry out classroom teaching. From this point of view, the scope of learning space is larger than that of teaching space.

(2) Learning space also implies that learning can occur in both physical and virtual scenarios. Therefore, the learning space also includes the physical learning space

and the virtual learning space. The organic coupling of the two can provide effective support for learning activities. With the wide application of information technology in education, teaching space has been extended from traditional physical space to teaching places including physical space and virtual space. From this point of view, there is no difference between learning space and teaching space, both of which contain physical space and virtual space.

(3) Learning space contains metaphors whose goal is to promote learners' learning. The teaching space represented by traditional classroom and teaching laboratory is more to provide support and service for teachers teaching. Students learning is limited to teachers' teaching. Learning space is from the perspective of learners, considering how to promote learners' learning by stimulating learners' interest in learning and supporting activities related to learning. Because the starting point of the two is different, there will be great differences between their external characteristics, forms, and the final impact on teaching.

(4) Learning space contains constructivist learning theory, situational cognition and learning theory, as well as knowledge and learning view of learning science. This can be confirmed by various prefixes in the current learning space. Many terms such as active learning, cooperative learning and student-centered are used to modify the learning space. The teaching space contains the concept of knowledge transfer, which holds that learning is the process of transferring knowledge from teachers to students, and teachers are the source and embodiment of knowledge. From this point of view, learning space and teaching space has a fundamental difference.

(5) Learning space contains that it needs to promote learners' learning through the enhancement of information technology. As mentioned above, learning space covers formal learning space and informal learning space, including both physical learning space and virtual learning space. Therefore, this paper holds that the concept of learning space also contains the metaphor of information technology enhancement. For teaching space, although the injection of information technology has become a common phenomenon, there are obvious differences with the purpose and model of injection in learning space.

2.2.2 Learning Space Design Framework

A design framework of learning space refers to a theoretical or practical structure that can guide the design, development, and evaluation of learning space. It usually specifies the process, steps, and factors (Britnell, J. C., Andriati, R., & Wilson, L. 2009) (Radcliffe, D. A., 2009) to be considered in the design process of learning space design. Some existing learning space design frameworks usually focus on one aspect of them, such as Britnell (Chen, 2010) which focuses on the design process of learning space. It is considered that the traditional design method ignores the demands of two most important stakeholders: teachers and students. Therefore, a multi-directional collaborative space design process is proposed, and the learning space of Rayson University is modified (Figure 2.4). The design process considers the interests of teachers, students, and planners, and supports teaching through space design and technology.

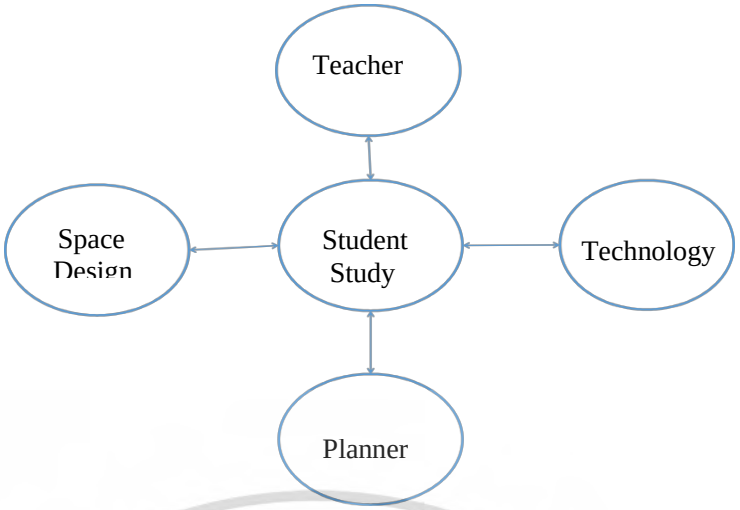

Figure 2.4 Multidirectional Design Flow for Learning Space

Purdue University of the United States proposed a PST framework (Wu,2011), PST is the abbreviation of Pedagogy-Space-Technology. PST framework was originally intended to effectively guide the design and evaluation of various formal and informal learning spaces. The framework consists of three interrelated and interacting core elements: pedagogy, space and technology, and an iteration is formed between the three elements (see Figure2.5).

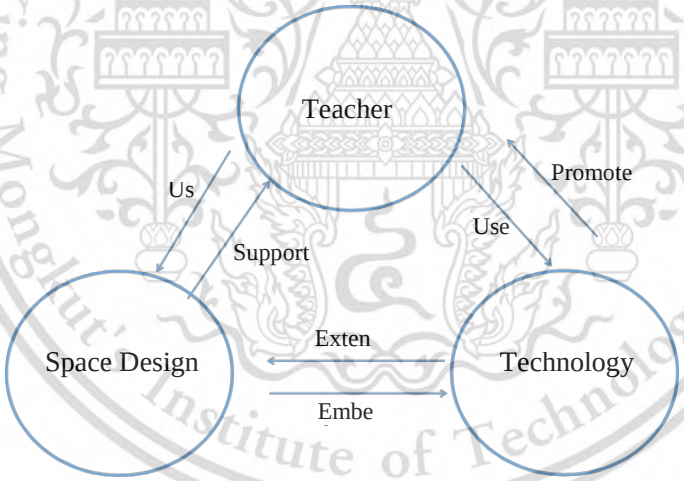

Figure 2.5 PST Framework

Teaching method realizes its idea and goal by using space and technology, and space" supports teaching method by embedding technology to realize the expansion of function, while technology promotes teaching method by embedding into space. In the design, we can consider the problem from the elements of teaching method, then consider the elements of space and technology respectively and consider the support and influence of the other two elements from any one element. Besides, the PST framework divides the life cycle of learning space design into two stages: idea and design and implementation and operation and details some specific problems that should be considered in the development of these two stages from four aspects: whole, teaching method, space, and technology respectively. For example, the idea and design phase should focus on the following questions as a whole: what is the initial motivation for

project development? What are the objectives of the project? How does the project start? Who are the supporters and opponents of the project? Who must be convinced? Why? What lessons can be learned in the future? Based on making clear the above problems, we can think about them from three aspects: teaching method, space, and technology, to consider all aspects of idea and design stage more comprehensively and systematically and provide support and guidance for the smooth development of implementation and operation stage.

Although the PST framework is not proposed for a long time, some learning space design projects have applied the framework. Such as Wilson and Randall use the framework to design, develop and evaluate the Pod Room. Among the few learning space design and evaluation frameworks, PST framework has put forward three core elements of learning space design earlier and clarified the relationship between them. This provides a useful reference for us to understand and grasp the learning space design. However, the framework simply divides the design process of learning space into two stages from the point of view of project practice and lacks the consideration of continuous optimization of space design. In addition, in these two stages, the framework presents several problems from four aspects to drive project development, but because these problems are too broad, both learning space design considerations, learning space use considerations, and scattered in different dimensions, these make the framework less operational.

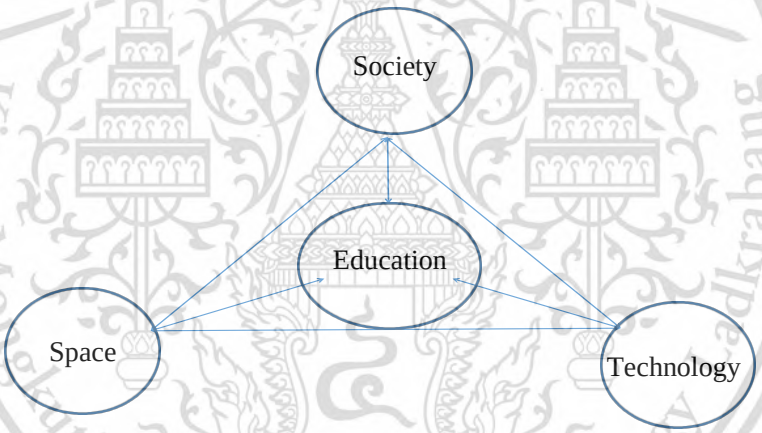

Figure 2.6 PSST Framework

There are also researchers to improve the PST the framework existing problems. For example, The Pedagogy-Social-Space-Technology framework is proposed by Chen Xiangdong based on PST framework. Aiming at the PST framework, which does not fully consider the ownership of competence, the establishment of projects and the source of funds, and the later management, The original three-dimensional framework was modified, classification of projects, funds, applications, management, and other social factors, called the “social dimension” (Social), thus forming a PSST framework (fig. 2.6) (Beichner, R. J., Saul, J. M., & Abbott, D. S. 2007). Like the PST framework, PSST framework also divides the design of learning space into two stages: project formation and design, implementation, and application, and from the whole, education, society, space, technology five aspects discussed. In the specific application of the framework (Breslow, 2010) have explored how to use the PSST framework to design and evaluate a seminar classroom. As an enhanced version of the PST framework, PSST framework enriches the elements of the learning space design framework, and there are problems like the PST framework. Based on the PST framework for learning space design life cycle division, on the other hand, it involves all aspects, not only failed to

promote effective design, instead, it increases the designer's load, and reduces the operability of the framework.

2.2.3 Learning Space Practice Project

There are five typical learning space projects in the world at present, named as SCALE-UP project, TEAL project (Xu & Chen，2013), TILE project (Spector, 2012) transforming university learning space project, future classroom project (Spector, 2014). These practical projects mainly focus on the design of physical space, pay attention to the role of information technology, and emphasize that the learning space should include flexible layout, circular desk, multi-screen space, information sharing and other functional features.

(1) SCALE-UP project is not a separate transformation of learning space, it is a set of solutions including teaching content, teaching methods, learning space, evaluation methods and so on. The objectives of the project are to create a learning environment that encourages students to collaborate with their peers and teachers; to use, as far as possible, teaching methods such as inquiry learning and experiential learning to reduce teaching methods; and to help students reflect and share rather than directly inform them of their answers.

To achieve the above objectives, the SCALE-UP project team, with the concept of learning pyramid theory, promoting deep learning, promoting collaborative learning, promoting active participation, etc., has carried out a multi-stage transformation of the traditional classroom, resulting in a learning space that includes round desks, easy access to relevant experimental equipment through surrounding wall cabinets, a group of 2~3 people with a notebook computer, a screen that can display and share information and a hand-held whiteboard. An internal scene of the SCALE-UP environment is shown in figure 2.7.

Figure 2.7 SCALE-UP Environment

(2) TEAL objectives of the project are to transform the teaching methods of college physics courses; to improve the pass rate of college physics courses; to create an attractive and technically supported active learning environment; to get rid of traditional passive teaching methods; to enhance students' ability to understand and analyze electromagnetic concepts; and to develop students' visual skills. TEAL environment is based on social constructivism as the theoretical basis of design, emphasizing the promotion of social interaction, encouraging students to take the initiative to learn, to

create an environment conducive to the transformation of traditional teaching concepts.

The educational theory, subject content and educational technology are the three basic elements (Huang, Yang, Hu, 2012) that the TEAL project team mainly considers when designing and developing the learning space supported by technology. Based on the educational guidance theory of social constructivism and the related results of visual research, the TEAL project team developed a system with dynamic experimental process simulation and 3D stereo vision graphics simulation using information communication technology and software according to the relevant knowledge characteristics of electromagnetism in college physics course. A learning space that can promote active and collaborative learning is constructed by combining experimental equipment, round desks, and real-time feedback system.

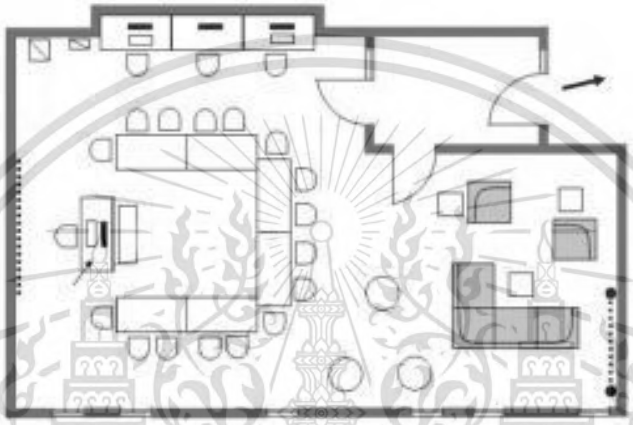

Figure 2.8 A Simulation of the First Teal Environment

(3) TILE, abbreviation of transform, interact, learn, engage, it means changing the role of teachers and students, promoting interaction in teaching activities, promoting active learning among students, promote student participation. TILE project was launched by the University of Iowa, August 2009, University of Iowa announced an investment of $15.5 million to build 6~10 active learning classrooms. The design concept of these classrooms is transformation, interaction, learning, participation. The interior scene of the classroom is shown in figure 2.9.

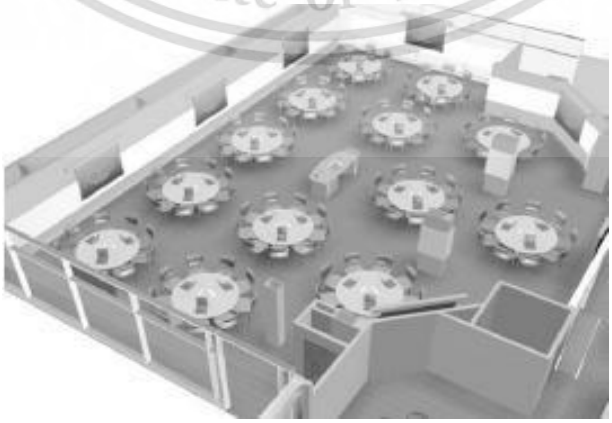

Figure 2.9 University of Iowa Active Learning Classroom

(4) Upgrading of university learning spaces. The project was initiated by the Australian Teaching Council (ALTC) under the Australian Department of Education. The Committee organizes research and practice at the University of Queensland, Edith Cowen University, Charles Darwin University and Deakin University. The goal of the project is to support active learning, collaborative learning, and peer teaching through the transformation of the original space. The project not only focuses on the transformation of formal learning space, but also on the transformation of informal learning space. At present, the project has achieved many academic research results, such as the PST framework mentioned above is one of the results of the project. The created learning space is shown in figure2.10.

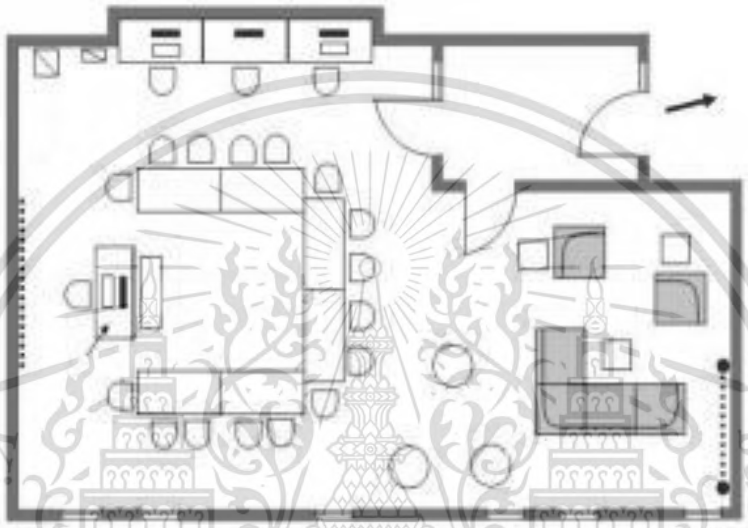

Figure 2.10 Study Spatial Structure of Deakin University

(5) The future classroom project explores innovative learning in the new technology environment as the research goal. Because of studying the influencing factors of classroom change, several learning space cases are designed and developed from the aspects of spatial layout, technology application and so on. Figure11 shows an internal scene diagram of a learning space constructed by the future classroom project group.

Figure 2.11 Future Class of East China Normal University

In recent years, influenced by the development of learning theory and technological progress. The reconstruction of traditional classrooms and laboratories has become a research hotpot in the world. To show the difference between traditional classroom and traditional laboratory in design concept and morphological characteristics. Researchers have come up with several terms to refer to this new thing: some refer directly to the project name, for example, technology-supported active learning (Technology Enabled Active Learning, TEAL). The project was launched by the Massachusetts Institute of Technology (MIT) in response to the low pass rate and high absenteeism in college physics, the researchers call the new environment they build TEAL environmental (Alexander, 2007). Some refer to design concepts, such as active learning space, active learning classroom, cooperative learning space, student-centered learning space, emphasize the design concept of this new environment to promote learners' active learning, cooperative learning, and student-centered learning; And researchers named it from an inter-generational perspective: The future classroom, the next generation learning space are the representatives. Currently, these terms are still widely used in specific areas, for example, future classroom has been widely used in China, EAL is widely used in the United States and Taiwan area, Active learning classroom and active learning space are also widely used in the United States, the next generation learning space is primarily used by Australian researchers.

Although the focus of the above research terms is different, but the researchers agree that their research belongs to the same field, learning space. From the perspective of promoting the development of the field of learning space research, "How to clarify the relevant concepts and their causes", "How to promote the dialogue and communication of researchers in this field" is a matter to be considered. With regard to the former, the evolving classroom and learning in virtual space can lead to the emergence of the concept of learning space; The White Paper on Learning Infrastructure published by the American Higher Education Informatization Association (EDUCAUSE) believes that the new teaching and learning methods and the emergence of virtual space lead to the concept of classroom finally evolving into a learning space (Learning Space) (Feng,2013). Regarding the latter, EDUCAUSE Quarterly has launched several topics to publish relevant research in the field of learning space to facilitate communication. A study space magazine (the Journal of Learning Spaces) was also officially launched in 2011. But as Brooks said, the study of learning space is at an early stage to clarify the concept of learning space from a more comprehensive perspective, analysis of the current research status and practical progress of learning space, it is great significance to promote the further integration of this field and to promote the research and practice in this field.

2.3 Information Technology Adoption

2.3.1 Information Technology Adoption Theory

In the 1980s, information technology has been widely used in various fields, but there is no special theory to explain the adoption behavior of information technology by users. As a prototype, the theoretical core of expectation theory model and self-efficacy theory is absorbed, and the technology acceptance model were proposed (Technology Acceptance Model, TAM).

TAM is a model that is used to study the behavior of information technology adoption from the perspective of psychology and behavior. More than 20 years after the TAM model was put forward, the researchers optimized the original model and put forward many improved model s and theories one after another, among which the TAM2、UTAUT are widely used.

(1) Rational Behavior Theory

TRA is the theoretical (Dishaw, M. T, Strong, D. M, 1999) of predicting individual behavior proposed by Ajzen &Fishbein in 1975. Suppose that the individual's behavior is made by rational thinking, and the individual's behavior is entirely by itself individual behavior, not be affected by unconscious factors.

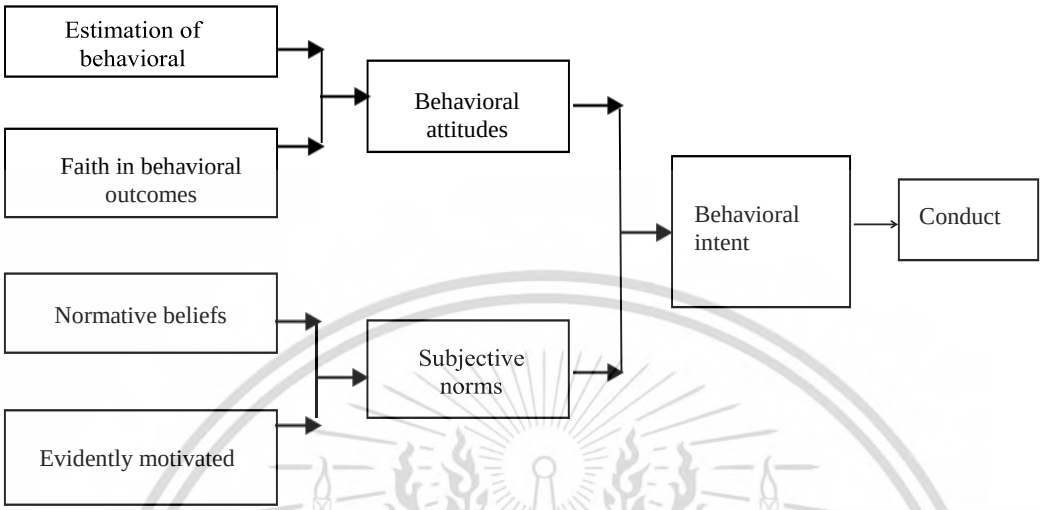

Figure 2.12 Theoretical Framework for Rational Behavior (TRA)

TRA is a common theory in the study of individual behavior, which has been proved to be effective in many fields of empirical research. Bidin (Dishaw M T, Strong D M, 1999) studied the willingness of Malaysian consumers to pay consumption tax, it is found that behavior attitude and subjective norms are significantly related to the willingness to pay consumption tax. Nguyen. (Venkatesh V, Davis F D, 2000) took TRA as the core in a study on the internal cooperation motivation of Vietnamese enterprises. The empirical results show that all the original paths in the TRA are effective paths. Allameh (Kim. J, 2006) based on TRA model, the influencing factors of knowledge sharing behavior of library staff are studied. The results show that the attitude and subjective norms of knowledge sharing have a significant impact on knowledge sharing willingness. This study proves that the TRA model can explain knowledge sharing behavior.

Although TRA has been proved in many fields to explain its behavior intention through individual attitude to behavior and subjective norms, this interpretation is too broad. Based on TRA, the Davis proposes a TAM. To explain the adoption of information technology and information systems in response to users' use of information technology

(2) Technology Acceptance Model

TAM two special beliefs of users, namely, perceived usefulness and perceived ease of use, are constructed as two key factors affecting the adoption of information technology by users. The TAM model is shown in figure 2.13.

Perceived usefulness refers to the degree of improvement in the performance of a user after using a certain information technology, while perceived ease of use refers to the ease of use of a certain information technology felt by the user. Perceived usefulness and perceived ease of use are influenced by many factors, including training, the degree of intervention of users in the design stage, TAM define these effects as external variables. Perceived usability positively influences perceived usefulness directly affect

the behavior intention, and the user's use of information technology is directly determined by its behavior intention.

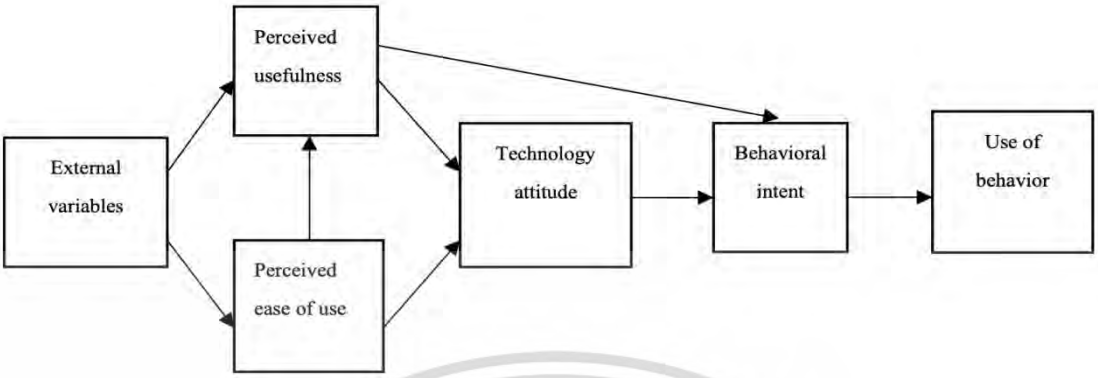

Figure 2.13 Technical Acceptance Model (TAM)

Although the TAM model can effectively explain the user's adoption of information technology, its definition of external variables is too general. External variables act on perceived usefulness and perceived ease of use at the same time, but TAM model does not clearly point out the specific external variables that affect perceived usefulness and perceived ease of use respectively. (Lee. Y., Kozar. K. A, Larsen, K. R. T., 2003) This caused TAM explanation ability is not strong, therefore is in TAM in view of the characteristics of the research object, the proper introduction of the theory of other fields is to improve the theory TAM effective parties to the capacity to explain type.

Venkatesh &Davis, 2000 (He, 2006) TAM, an extended technical acceptance model is proposed, which further refines the external variables acting on perceived usefulness ——TAM2-

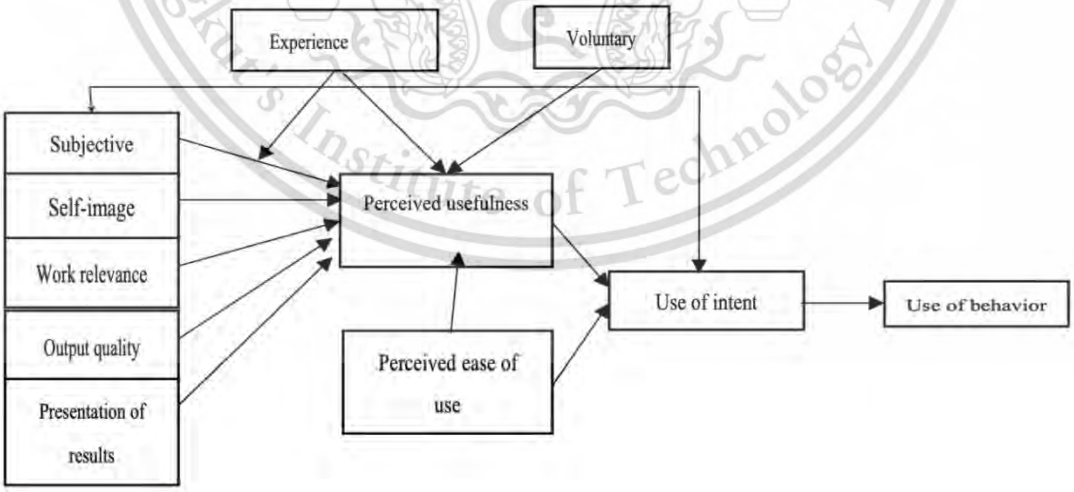

Figure 2.14 Extended Technology Acceptance Model (TAM2)

TAM2, the external variables are divided into two parts: social influence process and cognitive instrumental process respectively. The process of social influence

includes subjective norms and their own image, while introducing experience and voluntariness as regulatory variables; the process of cognitive tools includes work relevance, output quality and presentation of results. Social influence process and cognitive tool process jointly determine perceived usefulness, while subjective norms can directly act on behavioral intention under the regulation of experience and voluntary, perceived usefulness and perceived ease of use for use behavior are consistent with the TAM model. TAM2 have proved to be more effective than TAM in some of the newer IT adoption studies (Hsiao &Yang, 2011) (Marangoni. Granic., 2014).

Since TAM was put forward, to meet the needs of the actual situation of the research, TAM based research often improves and expands the original model. According to several documents, for extensions TAM. The main improvement and expansion methods can be divided into as shown in the diagram2.12 as shown.

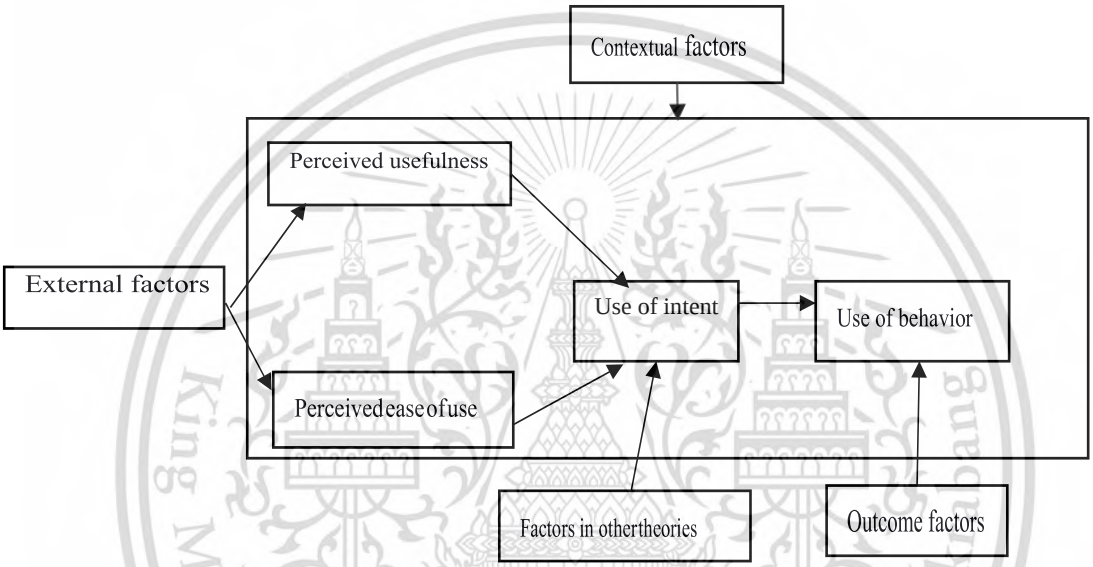

Figure 2.15 TAM Four Ways to Expand

(1) External factors

External factors include many pre-factors that can influence perceived usefulness and perceived ease of use, such as contextual involvement, previous experience in use (Duan& Guo, 2012), computer self-efficacy and belief in technology.

(2) Factors introduced in other theories

Factors introduced from other theories are mainly to improve the explanatory effect of TAM, including subjective factors specification, user participation trust and expectations (Wong &Huang, 2011).

(3) Outcome factors

Outcome factors are mainly measures of actual use, including attitude to perceptual use (Ignatius & Ramayah, 2005) and implementation, international use (Dasgupta, Granger, McGarry, 2002).

(4) Contextual factors

Contextual factors mainly regulate the original model path, such as age (Wong, Huang, 2011) gender (Padilla-Melendez, 2003) cultural diversity technical characteristics (Tarhini, Hone, , Liu, 2013).

2.3.2 Online Education Information Technology Adoption Model

To analyze the current situation of technology adoption in online education, this paper systematically summarizes the typical research cases in this field from the aspects

of research object, basic model, introduction of variables, expansion type and so on. The results are shown in Table 2.1. Among them, the extension types are classified according to the four TAM expansion methods mentioned in the previous section.

Table 2.1 Typical Research on Technology Adoption in Online Education

Author	Research subjects	Basic model	Introduction of variables	Type of extension
Wong, W. T.	E-Learning system	UTAUT	No	
Ignatius, J.	Online courses website	TAM	No	
Dasgupta, S.	Courseware management tools	TAM2	Skill level, outcome performance	3&4
Park, S. Y.	E-Learning	TAM	Organizational factors of self-efficacy, subjective norms, system availability	1
Tarhini, A., Hone	E-Learning environment	TAM2	Quality of work life	2
Gong, M.	Online education	TAM	Computer self-efficacy	1&2
Al-Adwan, A.	E-Learning	TAM	No	
Arteaga, S. R.	WebCT	TAM	Technical support, computer self-efficacy	1
Lee. Y.	E-Learning system	TAM	Comparative advantage, compatibility, complexity, testability, observability	1

Source: Based on references, the author concludes after summarizing the recent research on technology adoption in online education, I discover that:

1) Most scholars do not distinguish between online education and information technology in online education, the adoption of online education can be equated with the adoption of its core information system.

2) Most studies are carried out on the basis of extending the original classical model. These newly introduced variables come from many theoretical fields, such as innovation diffusion theory, flow theory, self-efficacy theory, and cognitive psychology and so on. Most of these new variables are a measure of the user's own factors, which shows that the existing studies consider the psychological characteristics of the user but ignore the essential attribute of online education as education.

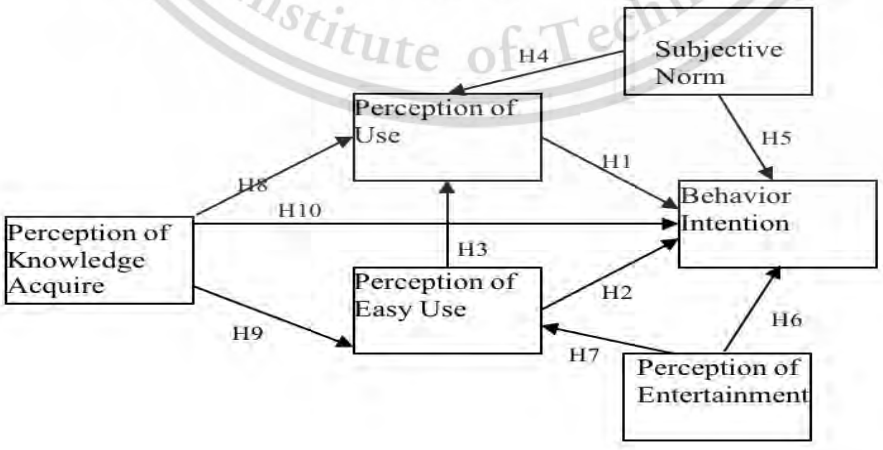

Figure 2.16 TAM model with Ubiquitous Learning Character

Grosseck pointed out that whether students in higher education use social media for learning depends on whether they perceive it as useful for their learning. Usluel believes that the adoption of Web 2.0 tools in distance education should be studied based on TAM, TRA, TPB, UTAUT and innovation diffusion theory.

To solve the tool support for effective learning in the ubiquitous smart learning space, this thesis decided to adopt the technology tools featuring social media, the purpose is to give learners familiar use habits and entertainment experience, so that learners can accept and maintain their willingness to use. Because the previous TAM technology model rarely studies technology adoption research based on social media learning, the author uses empirical analysis to obtain a technology adoption model based on ubiquitous characteristics through questionnaire surveys and data analysis and uses this conceptual model as a key point. The basis for the adoption of smart learning tool technology based on the framework model.

2.3.3 Analysis of Factors Influencing the Adoption of Ubiquitous Learning Characteristics

According to the various influencing factors involved in the research model as a division, the following discusses the empirical analysis results obtained in the previous section:

(1) Perceived usefulness and perceived ease of use

The empirical analysis results show that perceived usefulness and perceived ease of use have a significant impact on online learners' behavioral intentions of using social media, which is consistent with the findings of some traditional online education adoption behaviors (Ignatius Arteaga (Gong, Xu, Yu, 2004). Perceived ease of use has a significant impact on perceived usefulness, which is also consistent with existing research conclusions on traditional online education adoption behavior.

Learners' feelings about the usefulness and ease of using software in learning will affect their willingness to adopt. In addition, if learners find it easy to use software in their studies, they will also find this way of learning useful. Therefore, improving the ease of use of software in online education from the perspective of facilitating learners' use is crucial to enhancing learners' willingness to adopt. Lee (Al-Adwan, A., Smedley, J., 2013) pointed out that the compatibility, complexity, and relative advantages of e-learning systems are related to learners' adoption intentions and are also closely related to learners' perceptions of the system's usefulness and ease of use. It is worth noting that software applications are generally independent of LMS, and their separation from LMS may make it difficult for learners to use. Therefore, when introducing social media into online learning, it is necessary to evaluate the complexity of these technologies, solve the compatibility problem with LMS, and even modify the original LMS when necessary, so that it can be better integrated with LMS.

(2) Subjective norms. The empirical analysis results show that subjective norms have a significant impact on online learners' perceptions of usefulness, which is consistent with TAM2, and consistent with some research findings on online education adoption behavior. This shows that the concepts of teachers and surrounding students have an impact on learners' perception of usefulness. Therefore, teachers should pay attention to the promotion of online learning based on software, so that learners feel that this is a beneficial way of online learning. At the same time, the empirical analysis results also show that subjective norms have no significant influence on the intention of use behavior, which is like Allemeh, research on online education contexts, the main reason for the insignificant influence of subjective norms on behavioral intentions is that teachers only encourage learners to use learning space for learning, and the corresponding learning evaluations are not included in learning process. The introduction of usual tests and evaluation of learning results into learning probably

increase the willingness of learners to use learning space for learning.

(3) Perceived fun. The empirical analysis results show that the perceived interest has a significant impact on the intention of use behavior, which is consistent with the findings of some similar situations. This shows that learners feel interesting to for online learning, which will produce a happy and enjoyable learning experience, which in turn promotes their willingness to use. Therefore, teachers should give appropriate appreciation and encouragement to learners who actively participate in knowledge sharing, so that they can get more pleasant feelings, and then promote their further participation.

(4) Perceptual knowledge is available. The empirical analysis results show that the availability of perceived knowledge has a significant impact on perceived usefulness, perceived ease of use, and use behavior intentions. This shows that learners' perception of whether ubiquitous-based learning can effectively promote their knowledge acquisition has an impact on them. The feeling of whether this online learning method is useful and easy to use also directly affects the learner's willingness to use it. Learning provides a useful way for online learners to share and exchange resources on learning topics, and it also facilitates problem-based and action-based collaborative learning. Ubiquitous smart learning space should pay attention to how to introduce appropriate teaching models to help learners acquire knowledge more effectively. At the same time, space need to help teachers to play the role of coordinator, promote mutual communication between learners, and build a good collaborative learning environment, so that learners can feel that this learning method can improve their learning effects.

2.4 Summary of Smart Learning

2.4.1 Smart Learning and Smart Learning Space

Learning usually involves relatively stable and persistent of changes in cognition and behavior that occur in individuals or groups. Smart learning is to make our learning more intelligent than before. This smart can be a subjective feeling or an objective description.

Smart learning space can be understood as an intelligent learning system or platform, which cannot be separated from the support of intelligent learning environment and emphasizes the interaction between learning subject and environment. Intelligent learning environment refers to a learning place or activity space that can perceive learning situation, identify learners' characteristics, provide appropriate learning resources and convenient interactive tools, and automatically record learning process and evaluate learning results to promote learners' effective learning. Intelligent learning environment can realize the fusion of physical environment and virtual environment and can better provide learning support and service adapted to learners' personality characteristics. Its technical characteristics are mainly reflected in four aspects: recording process, identifying situation, connecting community, perceiving environment, etc. The purpose of this paper is to promote learners'easy, engaged, and effective learning. The former Honorary President of the American Association of Educational Communication and Technology Jonathan Michael pointed out that the difference between the smart learning environment and the general learning environment is that the design of the smart learning environment is to distinguish people's understanding, intelligence and ability and earning in an intelligent learning environment in which people can learn at any time (Any time), anywhere (Anywhere), in any way (Anyway) and at any pace (Any pace) (abbreviated as 4 A) can support learners to learn easily (Easy Learning), engaged (Engaged Learning) and effectively (3 E).

Ubiquitous smart learning space in this research is a complex system or smart learning platform specially designed to adapt to ubiquitous and smart learning. It supports the learning characteristics of 4A3E by creating a collaborative, lifelong learning, and social media learning environment, helping learners improve independent learning ability, collaboration, and critical thinking.

2.5 Collaborative Learning

The concept of collaborative learning, the grouping and pairing of students for the purpose of achieving an academic goal, has been widely researched and advocated throughout the professional literature. The term "collaborative learning" refers to an instruction method in which students at various performance levels work together in small groups toward a common goal. The students are responsible for one another's learning as well as their own. Thus, the success of one student helps other students to be successful. Proponents of collaborative learning claim that the active exchange of ideas within small groups not only increases interest among the participants but also promotes critical thinking. According to Johnson (1986), there is persuasive evidence that cooperative teams achieve at higher levels of thought and retain information longer than students who work quietly as individuals. The shared learning gives students an opportunity to engage in discussion, take responsibility for their own learning, and thus become critical thinkers. Despite these advantages, most of the research studies on collaborative learning have been done at the primary and secondary levels. Yet, there is little empirical evidence on its effectiveness at the college level. However, the need for noncompetitive, collaborative group work is emphasized in much of the higher education literature. Also, majority of the research in collaborative learning has been done in non-technical disciplines. The advances in technology and changes in the education put an increased emphasis on collaborative learning. Students need to be able to think creatively, solve problems, and make decisions as a team. Therefore, the development and enhancement of critical-thinking skills through collaborative learning is one of the primary goals of education technology. The present research was designed to study the effectiveness of collaborative learning with technology support.

It improves relationships and develops social skills so that they can interact much more freely. This technique enhances the learning process of an individual so that he can achieve learning efficiency.

(1) Boosts problem-solving skills

An important advantage of collaborative learning is that it helps in boosting the problem-solving skills. The students must discuss the work among themselves by conducting research, listening attentively, and communicating their thought process. Individual contributes to the discussion so that they all can come up with a solution for the given task.

It is the students that must find the solution and take a call for active participation and interaction. Students share and change their views if it is for the benefit of the team. Collaborative learning helps to find the right solution by improving and boosting problem-solving skills.

(2) Improving decision making skills

It develops self-management traits so that an individual can improve decision-making skills. Studying, researching, examining, and scrutinizing issues to find the right solutions is part of collaborative learning.

(3) Develops productivity and efficiency

Collaborative learning is about learning together in a group and developing interpersonal relationships. When people spend time with others, you learn to relate

with each other and become friends. These fosters trust and a sense of belonging that continues with time so that it increases the morale of a group and thus has a positive impact on their efficiency and productivity.

(4) Increases critical thinking

An important advantage of collaborative learning is that it increases critical thinking in an individual. It boosts the ability to grasp knowledge, learn, and transmit the information to others within the group. It is a learning experience that involves research and critical thinking so that he can think through the existing problems. When stimulating discussion takes place, the students clarify their viewpoints, ideas, and opinions in front of their group members. The interpretation and subsequent assessment nurture critical thinking in an individual.

(5) Builds trust

When you are working in a group, you must trust others to complete the project successfully. In this situation, the actual power rests with the group instead of a single person.

Every person has a definite set of skills and knowledge. Active participation builds trust amongst them and helps them to realize the value of shared knowledge and togetherness.

(6) Development of communication skills

Collaborative learning is a process where everyone can have own attitude within the group. During discussions, every individual must put forward his ideas and views.

This improves his oral communication skills. Sending of information, sharing it with others, receiving feedback, and concluding after deliberation cannot be concluded without proper communication amongst each other.

Explaining, expressing, listening, clarifying is all part of effective communication that improves during collaborative learning.

(7) Improves social interactions

An important part of the collaborative learning process is dividend an activity into tasks and subtasks. The students are divided into groups, each one charge one aspect of the job. In the end, they all must contribute towards completing the full task. This task has social relevance as it encourages effective communication skills. So collaborative learning is that it improves social interactions and teaches how to handle people from other groups to accomplish a task just like in social settings.

The data investigation tool is the “Team Collaboration Obstacle Evaluation Form”, which is originated from the book “The Five Dysfunctions of a Team”, wrote by (United States) Lancioni. Patrick The five major obstacles are: inattention of result, avoidance of accountability, lack of commitment, fear of conflict, absence of trust.

2.6 Critical Thinking

Benjamin Bloom (Bloom, 1956) and his associates are included in this category. Their taxonomy for information processing skills is one of the most widely cited sources for educational practitioners when it comes to teaching and assessing higher-order thinking skills. Bloom’s taxonomy is hierarchical, with comprehension at the bottom and evaluation at the top. The three highest levels (analysis, synthesis, and evaluation) are frequently said to represent critical thinking.

Educators have long seen critical thinking as a desirable educational outcome. More recently, the Partnership for 21st Century Skills has identified critical thinking as one of several skills necessary to prepare students for post-secondary education and the workforce. Furthermore, the newly created common core state standards reflect critical thinking ability. Although a concrete definition of critical thinking on which most

researchers can agree remains elusive, common areas of overlap exist among the various approaches. Typically, critical thinking is believed to include the component skills of analyzing arguments, making inferences by using inductive or deductive reasoning, judging, evaluating, and making decisions or solving problems. Background knowledge is believed to be a necessary, though not sufficient, condition for enabling critical thought within a given subject. Critical thinking entails cognitive skills, or abilities, and dispositions. These dispositions, which can be seen as attitudes, or habits of mind, include open- and fair-mindedness, inquisitiveness, flexibility, a propensity to seek reason, a desire to be well-informed, and a respect for and willingness to entertain diverse viewpoints. And transfer of critical thinking ability to new contexts is unlikely to occur unless students are specifically taught to transfer by sensitizing them to deep problem structures and are given adequate opportunities to rehearse critical thinking ability in a variety of domains.

The APA, for example, has specifically cautioned that its framework for critical thinking should not be interpreted as implying any kind of developmental progression or hierarchical taxonomy (Facione, 1990). A few empirical studies have investigated the evolution of critical thinking ability and abilities as students proceed through college. O'Hare and McGuinness (2009) found that the critical thinking scores of third-year university students in Ireland were significantly higher than the corresponding scores of first-year students. The authors speculated that attending university exerts an independent effect on the development of critical thinking. In a meta-analysis of eight studies from 1991 to 2000, Gellin (2003) concluded that college students who engaged in activities such as interacting with faculty and peers, living on campus, and participating in college clubs or organizations increased their measured critical thinking ability by 0.14 standard deviations as compared to college students who did not participate in such activities. 0.14 standard deviations as compared to college students who did not participate in such activities.

Han Dawei（2014） used the online writing teaching platform constructed by Dong Hongxue and Chu Shenghua (2010) as an online learning platform. The learning platform has six functional modules: network resources, teacher-student interaction, information release, homework submission and feedback, reflection diary and sample essay appreciation. The web resource module provides links to web corpus, foreign online writing laboratory websites and English learning websites, teachers upload writing resources, online writing exercises and other services; the information release function realizes real-time release of course information and writing tasks; the teacher-student interaction module provides BBS forums , Realize online synchronous and asynchronous communication, writing synchronous and asynchronous tutoring, to provide students with timely and effective help; the homework submission feedback module is used for the process evaluation of students' works; the reflection diary module records students' reflections on writing; the model essay appreciation module stores a large amount of Famous celebrities, masterpieces and typical student works of students are available for students to learn and appreciate. The article uses the Critical Thinking Personality Tendency Scale (Wen, Q. F., 2009) to examine five emotional traits: curiosity, openness, confidence, integrity, and perseverance. The test questions are extracted, and the reverse questions are modified into forward questions, which are used as the measure of this measure. There are 30 questions in total. The test uses Likert's six-level scale, the higher the score, the stronger the emotion. After the experiment, the critical thinking personality test scores of the two groups were subjected to an independent sample T test. The results showed that the experimental group was greater than the control group in varying degrees in the five emotional dimensions.

Among them, the curiosity gap is the largest, with an average score of 0. 5220, followed by openness, self-confidence, perseverance, and integrity. From the point of view of the significance of the difference, curious, self-confidence and perseverance are at 0. 01. There is a significant difference in the confidence level; the openness is at 0. The difference in the confidence level of 0.05 is significant; the difference in integrity is not significant. This shows that the teaching model has an obvious role in improving students' thinking personality tendency, especially curiosity, self-confidence, perseverance, and openness, but not much improvement in integrity. This may be because the age, experience, physiology, and psychology of college students have determined that they are close to maturity in terms of knowledge reserve, knowledge structure, intellectual development, and aspirations. One-semester courses cannot effectively change their basically solidified concepts. Based on the theory of action learning theory and blended learning methods, this research constructs a debating writing teaching model based on a computer network learning platform and conducts teaching experiments to explore how to cultivate students' thinking ability in writing teaching. The results of the study found that: firstly, the teaching model can effectively promote the development of students' speculative skills, especially the skills of analysis, reasoning, and evaluation; secondly, the teaching model can effectively cultivate the students' speculative personality tendency, making them more active and active and critically think deeply.

In terms of the development of measuring tools, nearly 30 types of measuring tools have been developed. The most influential ones include the California Critical Thinking Personality Tendency Questionnaire, the California Critical Skills Measurement Scale, and the Watson-Glaize Critical Thinking Evaluation Scale. To cultivate the ability of thinking, some scholars (Niedringhaus, 2001; Reed, 1998;) have studied the ways to cultivate the thinking ability of nursing, law, psychology, and biology students, and found that the task-based teaching method is effective. The thinking ability of the students in these majors has a better promoting effect. Wen Qiufang (2008) hierarchical model is the representative theoretical construction of the model of critical thinking in China. The CTDI-CV scale consists of 7 subscales, which measure the 7 traits of critical thinking tendency, namely, finding the truth (1-10), open thinking (11-20), analytic skill (21-30), systematic skill (31-40), self-confidence in critical thinking (41-50), thirst for knowledge (51-60), and cognition maturity (61-70). CTDI-CV mainly has been used to cultivate the thinking skill of nursing, law, psychology, and biology students, and found that the task-based teaching method is effective.

2.7 Related Work

Hwang, Wu-Yuin，Zhao, Lixinin， Shadiev, Rustam，Lin, Li-Kai，Shih, Timothy K，Chen, Hong-Ren（2020）designed geometry learning activities that students could apply newly learned knowledge to solve real-life problems, such as estimating the distance to real objects they find in their local community, measuring objects' length, width, and height, and calculating objects' surface area. They divided students into three groups, and each group used different tools in different contexts for the measurements and calculations: the students in control group A used traditional tools, such as rulers, paper, and pencil, and implemented their learning activities in the local community; group B used traditional tools as well, but implemented their learning activities took place in classroom; the students in the experimental group learned geometry in a local community setting using a tablet PC-based ubiquitous geometry (UG) system that we developed for this study. They tested the difference in geometry

learning performance, such as geometry reasoning and spatial estimation abilities, among the three groups. They also investigated the perceptions of students in the experimental group toward the UG system. Furthermore, they explore student behaviors toward measuring objects using the UG system and their relationship with geometry reasoning and spatial estimation abilities. The results showed that the geometry learning performance of the students in the experimental group was significantly better than that of the students in the other two groups. The results also showed that the students in the experimental group had high learning motivation and intention to use the UG system.

Vivien Lin, Yu-Hsuan Lin, Min-Chai Hsieh, Gi-Zen Liu, CA, Hao-Chiang Koong (2021) designed a multimodal ubiquitous learning application (MULA) with different augmenting effects for enhancing English as a Foreign Language (EFL) academic writing instruction. In a pilot project, 17 undergraduates engaged in ubiquitous learning and writing at a green building and provided survey responses and interview feedback about their ubiquitous writing experience. The surveyed (a) the ubiquitous learning model, (b) effective writing facilitation, (c) motivation, self-efficacy, and attitude, (d) self-regulation, and (e) system usability. Interview results further illustrated approaches of using MULA led to positive and negative experiences during ubiquitous writing. A final synthesis introduced seven affordances that made MULA a potential tool for enhancing writing instruction in EFL settings. And pointed that the seven affordances were effective design elements for multimodal context-aware ubiquitous learning. And they implemented multimodal ubiquitous learning applications in higher education.

Arajo, Rafael, D., Dora, Fabiano, A., Brant-Ribeiro, Taffarel, Cattelan, Renan, G., Ferreira, Hiran, N. M. (2020) pointed that it was necessary to consider people behave and learn in a different pace in the teaching/learning process. Based on cognitive theories, to explore students' learning styles (LSs) has positive impacts on learning outcomes. At the same time, Ubiquitous Learning Environments (ULEs) have the potential to make the multimedia authoring of Learning Objects (LOs) automatically, resulting on even larger educational content repositories and increasing more adequate presentation strategies to students. They proposed an approach for creating and personalizing LOs through a probabilistic proposal of the Felder and Silverman Learning Styles Model. And they integrated into a ubiquitous educational platform and experimented in real settings. Results indicate the existence of correlations between different types of interactions carried out by students and their respective LSs.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter explains the research methods used in this study. The main purpose is by innovating learning concept and educational technology method to enhance the learning space, the study proposal the ubiquitous smart learning space reconstruction model to improve the learning validity under the background of smart education and the COVID-19 pandemic. The central goal of this research is to (1) develop ubiquitous smart learning space design model to meet core learners and their interests to enhance collaboration and critical thinking ability (2) Whether the ubiquitous smart learning space effectively promote collaboration and critical thinking ability.

In this chapter, the researcher covers the research design, participants, and research tools, as well as the methods of data collection and data analysis at each stage of the research. This research aims to answer two main research questions:

3.2 Research Design

The following table shows the research process of the ubiquitous smart learning space:

The first stage: (Problem and Theory review, and need analysis) study the problem background, education change trends and theory of smart learning, smart learning space framework, and provide standards for the construction of ubiquitous smart learning space:

The third stage: (Development) construct symbiosis space system based on the ubiquitous smart learning space, and study satisfaction survey on its learning

The second stage: (Model) Core Learners and Its Core Interest Questionnaire Analysis, And Proposes the Concept and Core Framework of The Ubiquitous Smart Learning Space Community
environment.

The fourth stage: (Experiment) to study the effect of learning space on the improvement of learners' collaboration and critical thinking ability.

3.3 First Stage: (Theory Research) Study the Problem Background, Education Change Trends and Theory of Smart Learning, Smart Learning Space Framework, and Provide Standards for The Construction of Ubiquitous Smart Learning Space

3.3.1 The Learning Space Is Facing Continuous Reconstruction.

The ubiquity, ecology, and openness of the smart learning environment are offsetting the limited, single, and closed traditional learning environment. Institutions once predicted that in the next 50 years, half of the nearly 5,000 universities in the United States will disappear, and universities on the cloud will replace them. Undoubtedly, the world is already at a turning point from schooling model to online model, and the learning environment is being upgraded from campus learning to ubiquitous learning.

New technologies have promoted the evolution of social forms and the industrial

revolution, and the three together determine that the transformation of education is the development of smart education. The role of new technology on the level of smart learning, cloud + terminal and big data enable education resources to keep open and updated.

The learners strongly demand to solve various obstacles for acquiring continuous collaboration and critical thinking skill on the collaborate platform as adapting to lifelong learning has become people's survival instinct in the era of knowledge economy.

3.3.2 Key Technology

UNESCO IITE is a subsidiary institution specially set up for education. The goal of IITE is to create a borderless and more inclusive education supported by technology, to realize a knowledge-based society and popularize high-quality education. Education for all; The U.S. Department of Education proposed in the U.S. Educational Technology Development Plan 2010 that applied technology promotes student learning as a path to promote American system reform; at the same time, domestic education informatization is changing educational concepts and educational patterns. The combination of online education and offline education, mobile learning and fixed learning, collective learning and individual learning, independent learning and team learning, and knowledge learning and ability training are new engines of smart learning space. Based on those expectations, the research mainly uses the following technologies.

Gamification technology. Gamified learning has always had different perspectives. On the one hand: the organic combination of games and smart learning, in the form of connecting battles and competitions, enhances the interaction and interest of learning, and derives new learning model s and learning experiences; through the personalized and task-driven learning links, it brings learning real and sustainable stickiness.

Artificial intelligence technology. Technological advancements continue to optimize the learning experience, face, motion, and image capture and analysis. The purpose is to allow learners to truly experience the learning effects that match traditional classrooms through the Internet. Through continuous interaction, it provides a set of practical scientific problem analysis and solution methods while breaking the learners' inherent thinking stereotypes and expanding innovative thinking capabilities.

Interactive technology. Interactivity mainly reflects the intelligence of the courseware. The learning curriculum integrates teaching, learning, and practice, guiding users to actively participate in the learning process, triggering learners' active thinking, and improving learning effects.

Multi-experience Development Platforms (MXDPs) are tools for rapid development and deployment of applications. MXDPs are build engines in technology spaces (technology middle platform) that enable the construction of applications and the expansion of application spaces on the one hand, and the interoperability of data and processes between applications through open APIs on the other.

"Zhong tai", a concept first extended by Ali's big middle office, small front desk strategy proposed by Alibaba in 2015, was inspired by Supercell, a small Finnish company that set up a powerful technology platform to support many small teams in game development. This allows them to focus on innovation without worrying about basic but crucial technical support. 1). The "Zhongtai" is a business-oriented ability combination and reuse, providing integrated solutions: the purpose is to improve R&D efficiency and reduce the cost of innovation. It includes people, organizations, platforms, data, standards, specifications, and is a complete system of people and systems. 2). It is the natural evolution of the platform: the platform is the efficiency improvement of a single team, department, and system, while the middle office is the responsible

collaboration of multiple fields, multiple BU, and multiple systems. The “Zhongtai” is the natural evolution of platform, which brings about a decentralized organizational model, highlighting the differentiated construction of reuse, coordination, and business innovation. 3). The “Zhongtai” is not a system, it is a kind of system / ecology / methodology: it has standards and mechanisms to solve the problem of efficient collaboration and resource reuse of various business subdomains under the top-level field. The joint construction of various departments and business areas is the user and provider of it.

3.3.3 Standards for The Construction of Ubiquitous Smart Learning Spaces (Solution Principles).

The basic solution principles of the ubiquitous smart learning space (hereinafter referred to as USLS) are summarized as follows:

1. The fundamental goal of space construction and application is to give the smart education service model, promote the reform of education system and mechanism, promote the upgrading and transformation of learning, and adapt to the ubiquitous learning and smart learning.

2. The basic task of space construction and application is to provide collaboration educational application services, introduce social resources such as industries and institutions, support the lifelong education and smart learning space model, promote education equity, and improve the learning efficiency.

3. The important content of space construction and application is to aggregate learning process and learning management data, carry out academic analysis and learning diagnosis, accurately evaluate teaching effects, provide personalized learning services, support refined management and scientific decision-making, and promote artificial intelligence in application in teaching and management.

4. The core attributes of the space are sharing, interaction, and co-creation, and the basic characteristics are individualization, openness, collaboration, and adaptability.

5. The basic composition of space includes stakeholder space, symbiosis space, digital space, technological space.

6. The foundation of space construction and application is the accessibility of the network and various terminal access conditions for barrier-free access to space services.

3.4 Second Stage: (Model) Core Learners and Its Core Interest Questionnaire Analysis, Concept and Core Framework of The Ubiquitous Smart Learning Space Community

3.4.1 Core Learners and Their Core Needs Questionnaire Analysis

1. Participate: Data analysis of core functional requirements includes two forms: questionnaires and in-depth interviews. The subjects of the survey or interview are three kinds of learning-related stakeholders, namely managers, teachers, and students. For students, the author selected 477 students with online learning background; the work content of the managers is covering educational administration management, student management and administrative management, and they should have more than 10 years of continuous work experience as in-depth interviewees. The selection criteria for 10 teachers who have participated in the MOOC project and the open class project of the online education platform.

2. Research design: For students using questionnaire surveys, other stakeholders related to learning activities select focus groups and adopt in-depth interviews. The reason for this design is that before the formal questionnaire survey, the author conducted a small-scale questionnaire and found that the main problems are 1) learners only perceive the learning activities, they perceive that they need a lot of people to

support, but they can't describe the supporting processes and matching functions. 2)Teachers only pay attention to the implementation of teaching activities and the evaluation of teaching effects. They don't know much about the needs of learners, and teachers who are randomly selected have little understanding of the functions of the online education platform and the USLS so they cannot provide data, which leading to the failure of requirements analysis. 3）In China, take South West Forestry University as example, the managers have the most resources and decision-making power for the use of funds. They need to organize and coordinate resources to provide better services and scientific decision-making for teaching and learning. They are eager to manage activities through teaching and learning results and processes to control funds and resources with the purpose of cultivating certain skills of students, and they look forward to a prototype as a reference, and someone will help them transform their expectations into functional requirements and realize them. Therefore, after modification, the randomly sampling questionnaire survey design has been changed to focus on specific groups of people, in-depth interviews used for managers and teachers, questionnaire surveys are used for students.

(1) Questionnaire (Appendix1): it uses Likert 5 embodiment score scale design, divided into 3 portions, where the first portion is basic information, the second part is key function, third part is core stakeholder's need to be interacted with. This questionnaire was tried out with 30 participants and calculated for reliability as shown in table 3.1.

Table 3.1 Cronbach Alpha

N	Cronbach α
30	0.980

It can be seen from the above table that the reliability coefficient value is 0.980, which is greater than 0.9, indicating that the reliability of the research data is of high quality and can be used for further analysis.

(2) Interview outline (Appendix2): it includes 5 portions: basic information (7questions), business (job content) (6 questions), functional requirements (8questions), keep learning the strategy (3questions), strategies for improving learning skills (4questions), it takes 30 minutes to 60 minutes to answer.

Step1: Validity analysis. The author invited 5 relevant experts to analyze whether the test item is in line with the original content range and make a judgment to see whether the test item represents the original content or not, and based on comments, questions were modified again.

Step2: Carry out questionnaire. The author elaborates stakeholder concept and explain the definition of smart learning space firstly, then carried questionnaire and interviews.

(3) Data collection: the survey questionnaires are distributed on 477 copies randomly Alibaba data collection platform. Interview organized in face to face, videos and records were made, records should be assured with interviewees. Use Excel and SPSSAU to measure average score and rank.

(4) Data analysis: Use the "funnel analysis method" of software engineering requirements analysis to conduct a 5-layer analysis. The questionnaire selects the core functional design by comparing the average score; the interview content is trans-coded into documents through video and audio, and find out high-frequency requirements, each requirement is scored according to the mentioned frequency. If there is no obvious

gap among other requirements, the designer made a choice based on the funnel analysis method. After the functional analysis report is completed, an expert evaluation is required, and it is revised and improved again based on the evaluation results. Experts in this part need to have obtained the title of associate professor in related fields. It can be developed only after the functional framework is modified.

3.5 Third Stage: (Design) The Functional Model Design of The Ubiquitous Smart Learning Space.

1. To proposes architecture model and subspace model of the ubiquitous smart learning space, named symbiosis space, digital space, technology space and stakeholder space, and provides a detailed discussion of each subspace, combined with UML modelling description, to evaluate by experts and modified it to represent the specificity of each subspace form more clearly.

2. To systematically explains how to build, the building elements and different types of spaces in terms of the characteristics, model, elements, relationships, platform, and implementation of the ubiquitous smart learning space in conjunction with the smart center.

3.6 Third Stage: (Development) Construction of Symbiosis Space System Based on The Ubiquitous Smart Learning Space.

1. To choose develop platform and summarize development step of the ubiquitous smart learning space systemizing.

2. To develop the symbiosis space is an important component of the ubiquitous smart learning space and a learning place for learning stakeholders, consisting of a total of seven subspaces, such as interactive space, collaborative space, transmission space, creative space, inquiry space, social space, and private space.

3. To do users' satisfaction survey on learning environment in ubiquitous smart learning space.

Subjects

A survey and interviews were conducted on teacher and student satisfaction in three aspects: collaborative learning environment, collaborative learning activities, and collaborative learning effects, using the collaborative learning model as an example. The sampling method was used to randomly select five teachers for interviews and four classes with a total of 275 students for questionnaires (online anonymously). The questionnaire used a 5-point Likert scale, "very dissatisfied", "dissatisfied", "average", "satisfied", and "very satisfied" were recorded as 1, 2, 3, 4, and 5 points, respectively.

4. Give the function positioning and core technology implementation strategy with implemented components' UML diagrams and interfaces.

3.7 Fourth Stage: Learning Skills Improvement Experiment.

1. Population: There are 2 classes of 2nd year individually from computer science, data science, and system science, all of them are students from Big Data College of Southwest Forestry University in China, other two majors are fewer online learning and collaboration activities then computer science, so we selected computer science students as sample.

Sample: 64 students of computer science

In this experiment, cluster random sampling was used: to select 1 class out of 2,

(1) There were online courses and online collaboration. （2）Within each group, there must be great differences among the surveyed individuals, that is and academic levels, genders, ages.

2. Research design: use one group pretest and posttest design

The researcher defined the research design as: using the smart "Zhong tai" or middle platform as the technical support for the implementation of the ubiquitous smart learning space model, and conducting one group pretest and posttest, using Pared test to obtain the results.

Experimental design: O1 O2 X1 O3 O4

O1 refers to collaboration pretest score

O2 refers to critical thinking pretest score

X1 refers to learning with ubiquitous and smart learning space

O3 refers to collaboration posttest score

O4 refers to critical thinking posttest score

Step1: do the pretest of collaboration and critical thinking ability and static the levels.

Step2: ask experiment group learners learn "the software development and design" 20 weeks by ubiquitous smart learning space and complete internship report and project planning.

Step3: do the post-test on the learners and compare the average level on each element，interpret the results of the learning skill test based on the change trend of the average score of each element and the distribution ratio of the number of people.

3. Research Instruments

(1) Collaboration Assessment. The data investigation tool is the "Team Collaboration Obstacle Evaluation Form", which is originated from the book "The Five Dysfunctions of a Team", wrote by (United States) Lancioni Patrick. Lancioni is the president of Desktop Group, a management consulting company in San Francisco, and a well-known commercial best-selling author. He discusses issues of corporate leadership and organization management with tens of thousands of people every year. Professor Ning Xiangdong strongly recommends in the management class of Tsinghua University, so this scale is used as a data measurement tool.

The five major obstacles are: inattention of result, avoidance of accountability, lack of commitment, fear of conflict, absence of trust.

(2) Critical thinking inventory (CTDI-CV) (Appendix5) as question collection tool. The CTDI-CV scale consists of 7 subscales, which measure the 7 traits of critical thinking tendency, namely, finding the truth (1-10), open thinking (11-20), analytic skill (21-30), systematic skill (31-40), self-confidence in critical thinking (41-50), thirst for knowledge (51-60), and cognition maturity (61-70), each divided into six options from strongly agree to strongly disagree, with the positive questions being scored in the reverse direction, from "strongly agree" to "strongly disagree" on a scale of 6 to 1, respectively. each dimension score ranges from 10 to 60, with scores below 30 indicating a weak critical thinking ability of 30-40, 40-50 as model rate to high, and 50 or more as strong. Correspondingly, the total score range for the whole scale is 70-420, where a score above 350 indicates a strong critical thinking ability; between 280-350 indicates a model rate to high critical thinking ability; between 210-280 indicates a model rate critical thinking ability; and a total score below 210 indicates a weak critical thinking ability.

Table 3.2 Critical Thinking Scale Scoring

Dimensionality	Score interval value	Cut-off values			
		Strong	Upper Medium	Medium	Weak
Single quality	10-60	>50	40-50	30-40	<30
General quality	70-420	>350	280-350	210-280	<210

In this study, the pre-test of the Critical thinking ability Scale (CTDI-CV) was administered to 64 learners at the beginning of the study, and the data were tallied and tested for reliability, as shown in Tables 3.3, which showed that the reliability coefficient value of was 0.896, which is close to 0.9, thus indicating that the quality of the study data reliability is high and can be used for further analysis.

Table 3.3 Cronbach's Reliability Analysis

n	Cronbach α
30	0.896

Confirmatory Factor Analysis (CFA) was conducted on the scale, and the results showed that all the Average Variance Extracted (AVE) values corresponding to a total of 1 factor were greater than 0.5, and all the Composite Reliability (CR) values were higher than 0.7, implying that the data of this analysis had good convergent validity.

Table 3.4 Results of Model AVE And CR Indicators

Factor	Average Variance Extracted (AVE)	Composite Reliability (CR)
Factor1	0.578	0.903

（1）Collaboration Assessment Form Score evaluation :
8 ~ 9 the team does not have the above obstacles
6 ~ 7 the team has corresponding obstacles and needs attention
3 ~ 5 the team has corresponding

Table 3.5 Collaboration Assessment Form Score evaluation

The first obstacle (Absence of trust)	The second obstacle (Fear of conflict)	The third obstacle (Lack of commitment)	The fourth obstacle (Avoidance of accountability)	The fifth obstacle (Inattention of results)
Q1(1-3)	Q4(1-3)	Q7(1-3)	Q10(1-3)	Q13(1-3)
Q2(1-3)	Q5(1-3)	Q8(1-3)	Q11(1-3)	Q14(1-3)
Q3(1-3)	Q6(1-3)	Q9(1-3)	Q12(1-3)	Q15(1-3)
Mark(3-9)：	Mark(1-9)：	Mark (1-9)：	Mark(1-9)：	Mark(1-9)：

In this study, the pre-test and post-test of the scale were completed, and reliability tests were conducted, which showed that the reliability coefficient values of 30 copies of the scale were 0.971 and 0.971, respectively, which were greater than 0.9, thus indicating that the reliability quality of the study data was high and could be used for further analysis.

Table 3.6 Assessment Form Reliability Test

n	Cronbach α
30	0.971

(3) User satisfaction assessment (Appendix 3)

To guarantee evaluate the effectiveness of the implementation of USLS, we conducted a survey and interviews on teacher and student satisfaction in three aspects: collaborative learning environment, collaborative learning activities, and collaborative learning effects, using the collaborative learning model as an example. The sampling method was used to randomly select 10 teachers for interviews and four classes with a total of 275 students for questionnaires (online anonymously). The questionnaire used a 5-point Likert scale, very dissatisfied, dissatisfied, average, satisfied， and very satisfied were recorded as 1, 2, 3, 4, and 5 points, respectively. Two weeks after distributing the questionnaire, 263 copies were recovered, with a recovery rate of 95.64%.

Reliability analysis: Cronbach's coefficient was 0.973, and a total scale coefficient greater than 0.8 indicates that the scale has high reliability.

Table 3.7 Cronbach's Reliability Analysis

n	Cronbach α
30	0.973

4. Data collection

Table 3.8 Research Questions and Data Source

Research Questions	Data Source
1) Is it necessary to construct the ubiquitous smart learning space and who are the stakeholders and what are their core interests to enhance collaboration and critical thinking ability?	Literature; survey with 477 students and interviews with 10 teachers and 5 administrators
2) What elements should be included in a ubiquitous smart learning space?	The stakeholders and their core interests survey results
3) What are users' level satisfaction on ubiquitous smart learning space?	Survey with 275 students and interviews with 10 teachers
4) Can the ubiquitous smart learning space improve the leaners' collaboration and critical thinking ability?	Experiments on collaboration and critical thinking ability with 64 students

Table 3.9 Experiment Activity

Week	Activities
1	Pretest on collaboration and critical thinking ability
2-20	Carry out learning and design the software modeling process according to the seven links of problem situation, problem identification, inquiry learning, problem solving, result reporting, reflection and evaluation, and practical application in the activity and whole class need complete a software system modeling, during the process, exams, learning activities, teaching, student management involved in all kinds of stakeholders, including teachers, students, headteachers (present the role of administer), technology service provider.
21	Posttest on collaboration and critical thinking ability

5. Data analysis:

Compare the average score, standard deviation, and standard error before and after using the learning space using pair t-test.

CHAPTER 4

RESULTS

4.1 Analysis of The Stakeholders and Their Core Interests

This survey selects college students as the research object and aims to survey the core requirements of ubiquitous smart learning space functions design through seven aspects: interactive function, collaborative function, teaching function, inquiry function, creative function, private function, and social function. This questionnaire is divided into three parts: the first part has 4 questions, which are basic information questions; the second part has 2 questions, mainly to understand the use of learning platforms by college students, such as which digital devices they have and which learning platforms they have used. The third part is the core part, with 7 major questions and 36 sub-questions, mainly to understand the functional needs and suggestions of college students for the ubiquitous smart learning space. In this survey, 477 questionnaires were recovered, and the incomplete questionnaires were excluded. Finally, a total of 476 valid questionnaires were counted from 28 majors.

Table 4.1 Analysis of The Basic Composition of Students

Name	Options	Number	Percentage (%)
Gender	Female	252	53.57
	male	221	46.43
Age	20<	85	18.06
	⩾20	389	81.84
Major	Transportation	149	3.15
	Physical Education	129	2.73
	Agricultural Resources and Environment	1	0.21
	Chemical Engineering and Technology	20	0.42
	Land Resource Management	20	0.42
	Geographical Sciences	178	3.78
	Business Management	72	15.13
	Applied Chemistry	7	1.47
	Data Science and Big Data Technology	28	6.09
	Tourism Management	89	1.89
	Mechanization Engineering	17	3.36
	Mechanical Design and Manufacture and Its Automation	12	2.52
	Forestry	10	0.21
	Forest Products Chemical Industry	8	1.68
	Forest Protection	30	0.63
	Plant Protection	10	0.21
	Soil And Water Conservation and Desertification Control	9	1.89
	Automotive Service Engineering	17	3.57

Table 4.1 (Continued)

Name	Options	Number	Percentage (%)
	Environmental Engineering	4	1.05
	Environmental Design	50	10.50
	Ecology	30	0.63
	Electronic Information Engineering	8	1.89
	Electronic Science and Technology	20	0.42
	Physical Geography and Resource Environment	10	0.21
	English	8	1.68
	Computer Science and Technology	146	30.88
	Vehicle Engineering	9	1.89
	Wildlife And Nature Reserve Management	7	1.47
total			100.0

In terms of gender distribution, there are slightly more female than male, with 53.57% of female and 46.43% of male; in terms of age distribution, 81.84% are students ≥20; in terms of major distribution, most of them are engineering and forestry, the ratio is 78.57%. In addition, the proportion of cultural, industrial, and commercial categories is 21.43%.

We analyze the basic conditions for students by analyzing the digital devices owned by students. Table 4.2 presents a summary of the response rate and penetration rate of digital devices owned by students.

Table 4.2 Response and Popularity Rate for Digital Devices

Categories	n	Response rate	Popularity rate (n=476)
Desktop PC	33	3.31%	6.95%
Laptop	400	40.08%	84.21%
Tablet	90	9.02%	18.95%
Smart Phone	475	47.60%	100.00%
Goodness of fit: χ^2=584.421 p=0.000			

The response rate and penetration rate of laptops and smart phones are significantly higher, especially the penetration rate of smart phones has reached 100%, which means that all students have the basic conditions to carry out smart learning and smart phone adaptive has the priority.

4.2 Key Function Analysis

There are 7 categories, namely interactive function, collaborative function, teaching function, inquiry function, creative function, private function, and social function.

4.2.1 Analysis of Interactive Functional Requirements

Table 4.3 Interactive Features Descriptive Analysis

Items	Mean	Std. Deviation	Meaning
Instant Messaging	4.374	0.891	Necessary
The Message Must Be Reached	4.355	0.905	Necessary
Voice Conference	3.947	1.129	Necessary
Video Conference	3.840	1.180	Necessary
Online Translation	4.013	1.056	Necessary
Other Interactive Features	2.393	1.942	Unnecessary

5 interactive main functions given in the questionnaire, the mean is or very close to 4.0, indicating that students need these 5 functions.

4.2.2 Collaborative Functional Requirements Analysis

Table 4.4 Collaborative Features Descriptive Analysis

Items	Mean	Std. Deviation	Meaning
Online Documentation	4.200	0.954	Necessary
Shared Storage	4.071	1.064	Necessary
Learning Circle	4.034	1.036	Necessary
E-Mail	3.878	1.151	Necessary
Project Management	3.914	1.127	Necessary
Other Collaborative Features	1.912	2.038	Unnecessary

5 main functions of collaboration given in the questionnaire, the mean is or very close to 4.0, indicating that students need these 5 functions.

4.2.3 Teaching Functional Requirements Analysis

Table 4.5 Teaching Features Descriptive Analysis

Items	Mean	Std. Deviation	Meaning
Smart Classroom	4.065	1.045	Necessary
MOOC Learning	3.891	1.143	Necessary
Micro-Learning	3.815	1.159	Necessary
Short Video	3.935	1.115	Necessary
Live Online	3.851	1.188	Necessary
Online Class	3.998	1.114	Necessary
Other Taught Functions	1.611	1.971	Unnecessary

6 main teaching functions given in the questionnaire, the mean is or very close to 4.0, indicating that students need these 6 functions

4.2.4 Exploratory Functional Requirements Analysis

Table 4.6 Exploratory Features Descriptive Analysis

Items	Mean	Std. Deviation	Meaning
Mind Mapping	4.042	1.033	Necessary
Digital Laboratory	3.853	1.131	Necessary
Digital Library	3.929	1.138	Necessary
Smart Search	4.076	1.062	Necessary
Smart Writing	3.912	1.100	Necessary
Other Exploratory Functions	1.643	2.015	Unnecessary

5 main functions of teaching type given in the questionnaire, the mean is or very close to 4.0, indicating that students need.

4.2.5 Analysis of Creative Functional Requirements

Table 4.7 Creative Features Descriptive Analysis

Items	Mean	Std. Deviation	Meaning
AR design	3.655	1.307	Necessary
VR Design	3.634	1.298	Necessary
3D experience	3.647	1.285	Necessary
Application Design	3.729	1.250	Necessary
data analysis	3.819	1.195	Necessary
Other creative features	1.639	1.984	Unnecessary

5 creative main functions given in the questionnaire, the mean is or very close to 4.0, indicating that students need these 5 functions.

4.2.6 Analysis of Private Function Requirements

Table 4.8 Private Features Descriptive Analysis

Items	Mean	Std. Deviation	Meaning
Personal Circle	3.935	1.185	Necessary
Personal Storage	4.095	1.077	Necessary
Encrypted Transmission	3.998	1.102	Necessary
Secret Chat	3.788	1.288	Necessary
Share Privately	3.834	1.250	Necessary
Other Privacy Features	1.567	1.992	Unnecessary

5 private main functions given in the questionnaire, the mean is or very close to 4.0, indicating that students need these 5 functions.

4.2.7 Analysis of Social Functional Requirements

Table 4.9 Social Features Descriptive Analysis

Items	Mean	Std. Deviation	Meaning
Circle Of Friends	3.968	1.141	Necessary
Social Network	3.941	1.135	Necessary
Knowledge Service	4.036	1.041	Necessary
Social Practice	3.964	1.094	Necessary
Subject Competition	3.761	1.195	Necessary
Other Social Functions	1.540	1.982	Unnecessary

5 main social functions given in the questionnaire, the mean is or very close to 4.0, indicating that students need these 5 functions.

4.3 Comprehensive Function Analysis of Ubiquitous Smart Learning Space

A comprehensive analysis of the seven functions of the ubiquitous smart learning space, including interactive functions, collaborative functions, teaching functions, exploratory functions, creative functions, private functions, and social functions.

4.3.1 Analysis of Learning Platform

We look at the learning platforms and software students have used in the past by response rate and penetration rate, and Table 4.10 provides a summary of usage.

Table 4.10 Response and popularity rate for learning platforms

Categories	N	Percent (n =476)
MOOC	299	62.82%
Social network	416	87.39%
Short video	376	78.99%
Weibo	285	59.87%
Knowledge service	284	59.66%
Wiki	244	51.26%
Micro Lesson	87	18.28%
Google Classroom	98	20.59%
Other platforms	50	10.50%

Social networks, short videos, MOOCs, Weibo, and knowledge services have significantly higher rates. Social network is 87.39% and short video is 78.99%, it means fragmented learning has gradually become the mainstream of knowledge acquisition and learners' eager social involvement during learning.

2.34% of the students also mentioned other learning platforms, and analyzed the platform names given by the students, mainly focusing on online learning platforms such as NetEase Open Class, Tencent Classroom, We Learn, Wisdom Tree and You

Academy, as well as interactive platforms such as DingTalk and Instagram. Based on the existing learning platforms and applications, none of them can cover the seven application functions of our proposed ubiquitous smart learning space: interactive functions, collaborative functions, teaching functions, exploratory functions, creative functions, private function, and social function.

4.4 Result of Research Question Two

4.4.1 Analysis of Learning Space

The characteristics of instructional spaces in terms of physical form include such elements as size, shape, the degree of closure or openness of the space, and the degree of flexibility in adjusting the combination of spaces. Learning space has an impact on both cognitive and non-cognitive abilities of learners (Yu, 2018). With the deepening of the understanding of learning by emerging learning theories, the extensive integration of information technology in education and teaching, and the emphasis on informal learning by the concept of lifelong education, the relationship between traditional learning spaces and specific teaching concepts has been greatly transformed and a new understanding of the connotation of learning spaces has been formed. It is revealed in the following six aspects.

1) The learning space is detached from the traditional classroom and shifted from the physical field to a seamlessly integrated learning space under the concept of ubiquitous learning.

2) Learning space shifts from a physical space to a hybrid learning space that integrates virtual and reality (Wu, 2017).

3) Learning spaces have shifted from spaces supported purely by manufacturing technologies to spaces supported by multiple technologies. With the development of information technology and its application in education, a variety of technologies and devices such as big data, cloud computing, Internet of Things, and context-awareness are widely used in the construction of learning spaces.

4) Focusing on how to facilitate learners' learning and give more consideration to stimulating interest in learning, supporting learners' learning process and providing them with convenient support services in the construction of learning spaces.

5) Learning spaces embody a variety of model learning theories and learning perspectives. Active learning, inquiry learning, collaborative learning, and connected learning views of knowledge and learning are integrated into the construction of learning spaces, this has changed the previous concept of learning spaces' construction.

6) Emphasized on the integration of teaching and learning related elements. The design of learning spaces, the explicit analysis of the model s and mechanisms of action between teaching and learning elements provide diverse options for enhancing the learning effectiveness of learners.

A learning space is an interactive learning field composed of learners, teachers, learning content, learning tools, learning environment and other elements, providing learners with interactive communication, work display and learning tools and other support for open learning places. The construction of learning spaces is increasingly focused on building a smart learning environment to promote learners' smart learning (Zhang, Peng, 2017). Learning spaces and context-based big data, adaptive learning paths, Virtual and real integration of creative education, big data-based learning analytic (Song, 2020) and other correlations become a smart learning environment that supports smart education, promotes smart learning, and enhances learning effectiveness, driving a shift in the learning paradigm from instruction, inquiry, and adaptation to multiple complexes and smart choices.

4.4.2 Smart Environment and Its Characteristics Analysis

Smart learning environment can realize the integration of physical and virtual environments and can better provide learning support and services that adapt to learners' individual characteristics. The learning under the smart learning environment is mainly knowledge-linked learning, and emphasizes learning environment with multiple specifications, multiple paths, and multiple evaluations. The smart learning environment provides effective support, such as perceives the learning situation comprehensively, identifies the characteristics, appropriate learning resources and convenient interactive tools, and can automatically records the learning process and evaluates the learning results through model with high technology such as Internet of Things technology, big data systems and artificial intelligence technology.

The smart of the ubiquitous smart learning environment involves five dimensions: Showing, Manageable, Accessible, Real-time Interactive, and Testing, abbreviated as "SMART" conceptual model. Figure 4.1 shows the conceptual model of a smart learning environment.

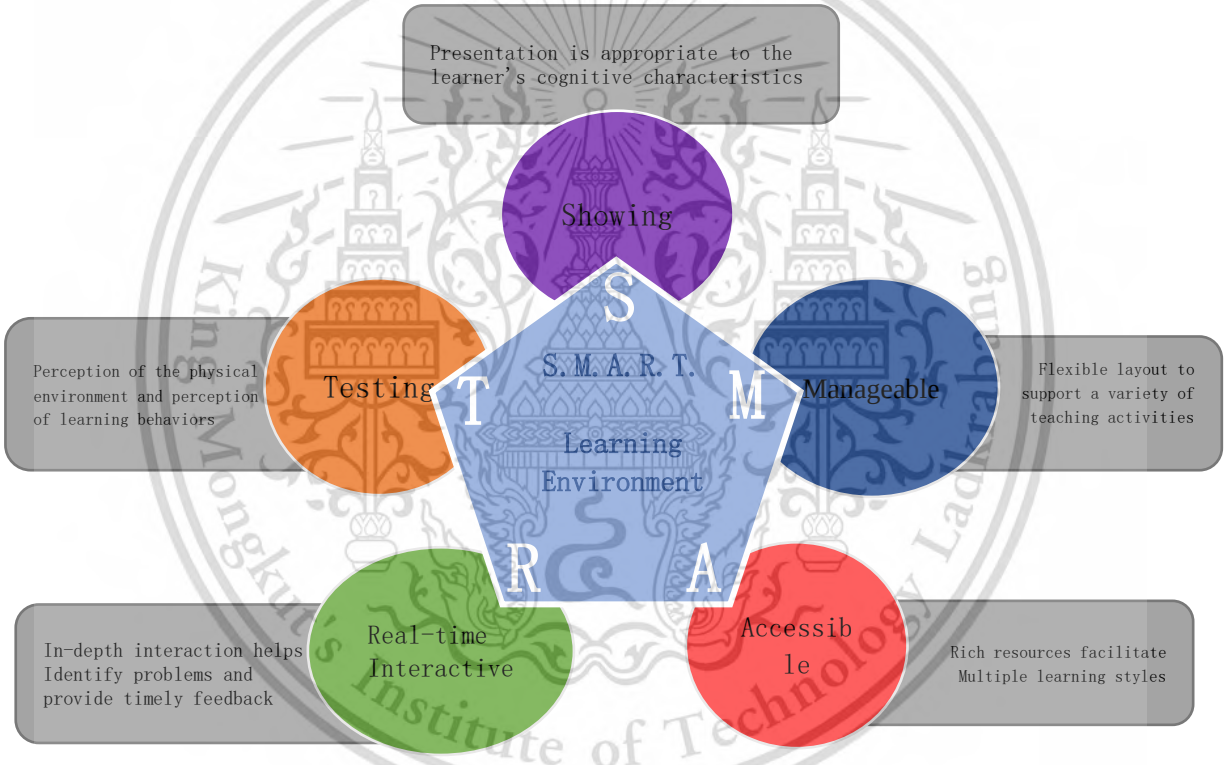

Figure 4.1 Conceptual Model of a Smart Learning Environment

1) Showing. The main characterization is the ability to present in a smart learning environment, which requires not only the presented content can be clearly visible, but also the way of presenting content is suitable for learners' cognitive characteristics and helps to enhance learners' understanding and processing of learning materials.

2) Manageable. It means the smart learning environment is the diversity of functional layout and management convenience, and the flexible functional layout, can support a variety of teaching activities.

3) Accessible. The main characterization is the resources accessibility and the convenience of device access, and the rich teaching resources provided are conducive to

the realization of multiple learning styles.

4) Real-time Interactive. The main characterization is the ability to support learning interaction and human-computer interaction, which can fully support the deep interaction of teaching and learning, and timely find students' difficulties and problems during the interaction process then guide or help them.

5) Testing. It is the ability to perceive learning behavior, air, temperature, light, sound, color, smell, and other environmental factors that directly affect the teaching and students' physical and mental activities.

The main difference between the ubiquitous smart learning environment and the traditional learning environment is that it makes full use of the present information technology to strengthen interpersonal psychological compatibility and communication, to improve learning efficiency in a wider and more paradigmatic way, to build dynamics collaborative learning environment in which everyone learns anywhere, anytime on any devices.

4.4.3 Ubiquitous Smart Learning Space User Analysis

Stakeholders are any group or individual who can influence or be influenced by the achievement of the organization’s objectives (Song, 2020). Based on the stakeholder theory, we used literature analysis and qualitative analysis to define four types of core stakeholders, namely, students, educators, administrators, and service providers. Through researching on their interests, it is showed that students most concerned about the content and function of learning spaces, educators are concerned about feedback and guidance, administrators are concerned about supervision and management, and service providers are concerned about convenience, efficiency, interest. And they collaborate and co-built the leaning space. Based on this research, we define the learning stakeholders as ubiquitous smart learning community.

Ubiquitous smart learning community consist of students, educators, administrators, and service providers, the students are the main body of learning, and the other stakeholders must start an in-depth dialogue with the students to stimulate the students’ original knowledge experience, promote their reflection on new and old knowledge, and facilitate the transfer of knowledge in new contexts. The conceptual model of learning stakeholders is given in Figure 4.2.

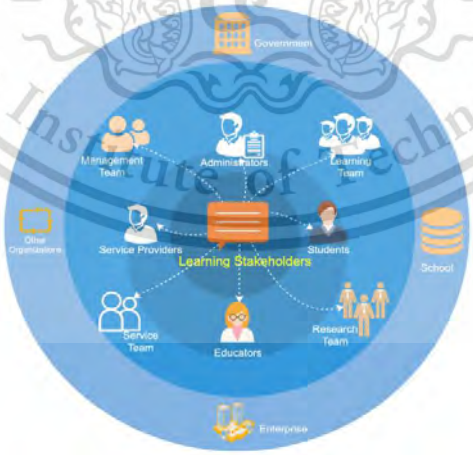

Figure 4.2 Conceptual Model of Learning Stakeholders

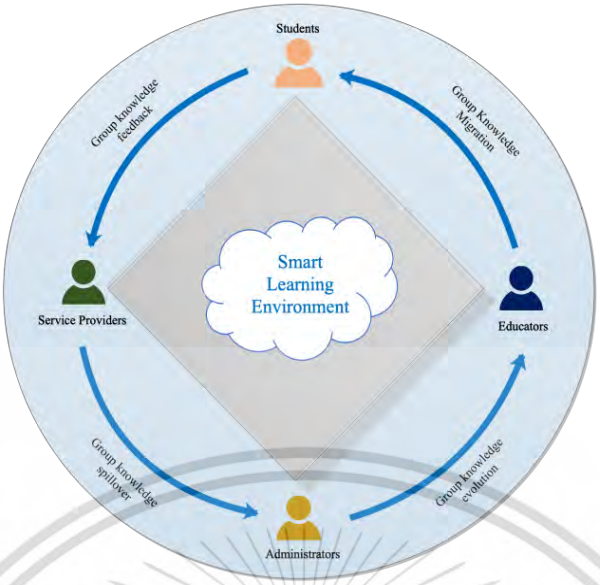

Figure 4.3 Model of The Relationship Between Learning Stakeholders and Smart Learning Environments

There are three main categories activities and needs when ubiquitous smart learning community in the learning space.

(1) Interaction and Communication

Learners face some common difficulties, 1) deal with conflicts between studies, work, and family. 2) Moreover, the smart learning approach is new to the learners, and they must adapt to it, especially to learn to use the various technological tools. Due to those difficulties, many learners are unable to sustain their learning to the end. Therefore, learners need better interactive support. To this end, USLS can provide guidance to learners through face-to-face coaching, scenario-based Q&A, or counselors on how to effectively manage their use of time and how to use various technology tools and how to communicate on social media. In addition, learners can share their experiences and feelings with each other and offer advice to each other. Through this interactive communication, learners can experience mutual acceptance and support, thus increasing their motivation to overcome difficulties and engage in learning.

(2) Guidance and Exploration

Smart learning groups contain educators, administrators, and service providers who are important facilitators who will play a guiding support role in their interactions with learners, and they are important parts of the smart learning resources.

In a smart learning community, educators can provide feedback and guidance to learners on their learning activities and facilitate their communication and reflection activities. Educators need to become learning facilitators（Shang, 2020) who engage in in-depth dialogue with learners to stimulate their original knowledge experiences, facilitate their reflection on new and old knowledge, and promote the transfer of knowledge in new contexts.

In a smart learning community, educators may ask learners enlightening questions, or they may help them form hypotheses, or form their own judgments and opinions. With the help of a smart platform, this dialog communication can reach a high degree of individualization and bring out the subjectivity of individual learners. The educator is no longer solely the initiator and controller of intelligent learning but is

involved to a greater extent as a partner of the learner in the communication activity. In this communication, learners are the constructors of knowledge and are engaged in active exploration and discussion activities. Learner-recentness is the principle of action that educators of smart platforms should implement.

In addition, compared to traditional teaching, smart platforms can more easily bring subject matter experts into smart learning to participate in discussions and communication with learners. Subject matter experts can provide learners with a variety of practical examples and case studies related to the content being learned, provide a variety of feedback, and demonstrate a variety of different perspectives and problem-solving ideas. In addition, they can provide learners with up-to-date information resources related to the current content and guide learners in further exploration of the issue. This allows learners to go beyond the boundaries of the team space and the readily available information they are exposed to, further connecting to real-world problem situations, and increasing the flexibility of the knowledge gained.

(3) Communication and Cooperation

In smart learning community, learners interact with each other to facilitates their cognitive activities. Using interactive collaboration functions, learners can discuss and exchange ideas around learning topic, form their own judgments, express their own understanding of problems and different solutions for solving them, also can solve doubts, argue, and evaluate, cooperate with each other. Communication and cooperation in USLS can facilitate the acquisition and application of knowledge, can promote the depth of learners' learning and reflection activities, and increase their need to learn as well as their self-awareness of learning activities.

4.4.4 Definition of Ubiquitous Smart Learning Space and Its Constituent Elements

(1) Definition

Ubiquitous smart learning space is defined as a learning environment that embodies the concept of smart learning and supports learners to learning smartly. It allows learners to access it at any terminal to get the opportunity to learn anytime, anywhere, on-demand, and can push appropriate learning resources and tasks for learners through the perception of learning situations and the analysis of learning data, thus realizing the development of learners' thinking, the improvement of their behavioral ability and the stimulation of their creative potential, with the characteristics of smart, integration, creativity, contextualization, and openness.

1) Smart is reflected in the ease of access to resources, the customized learning support, the adaption of the learning process and the multidimensional evaluation of learning outcomes.

2) Integration refers to integration of multiple learning theories, intelligent technologies and platforms, and multiple types of data.

3) Creativity means that it is constructed under the goal of fostering innovative capabilities and tools that can effectively foster learners' creativity.

4) Contextualization means that it creates a learning context that is interrelated with words, images, and meanings through the flexible use of technology, thus awakening learners' motivation to learn and innovate.

5) Openness means that the smart learning space is a system that is compatible with other spaces, can maximize interfaces for various devices and applications, and can be embedded in the resources of other learning spaces or the space itself, thus achieving seamless integration with other learning spaces.

Based on the above analysis, we give the definition of ubiquitous smart learning space.

Ubiquitous smart learning space is an open and smart learning environment based on ubiquitous network and cloud computing, supported by resource sharing,

powered by a smart middle platform, and driven by collaborative interaction, integrating multiple stakeholders, and supporting learners to learn easily, engagingly, and effectively.

The ubiquitous smart learning space allows the diversity of learners and individual differences to be valued, enabling the realization of the concept of "learner-centered" education, and presenting three basic features.

First, easy learning, which is a prerequisite for engaging in learning. The ubiquitous smart learning space provides a convenient learning atmosphere to make the learning easy for learners.

Second, engaged learning, which is a prerequisite for effective learning. Ubiquitous smart learning space can stimulate and promote learners' interest in learning, keep learners' interest and participation in a high state, and communicate and collaborate well with peers at any time, and learners in this learning environment are engaged.

Third, effective learning, which is the goal of smart learning. The learning results under the learning space are basically in line with or even higher than expected.

(2) Ubiquitous Features

In addition to the characteristics of smart, integration, creativity, contextualization and openness, the ubiquitous characteristics of ubiquitous smart learning spaces are reflected in the following aspects.

1) Ubiquitous network is a widespread and ubiquitous network. In other words, people are placed in the ubiquitous network, realizing the information exchange with anyone real time, and providing ubiquitous and all-inclusive information services and applications for individuals and society-based needs. The gradual maturity of mobile Internet (Zheng, Wu. 2011) is the basic guarantee to realize ubiquitous.

2) Ubiquitous stakeholders. The ubiquitous smart learning space fully integrates multiple stakeholders in learning, namely learners (students), educators (teachers), administrators, and service providers. The stakeholders are ubiquitous. They can be driven by collaborative interaction, interacting, and communicating, guiding, and exploring, communicating, and cooperating, sharing various learning resources to influence and promote each other at real time

3) Ubiquitous cloud platform.

(1) Cloud computing is an Internet-based computing approach through which shared hardware and software resources and information can be made available on demand to various terminals of computers and other smart devices using computer infrastructure provided by service providers for computing and resources. Cloud computing is also a new Internet-based model for the addition, use and delivery of IT services, often involving the provision of dynamically visualized resources over the Internet (Spector, 2014). Learning stakeholders no longer need to understand the details of the infrastructure in the cloud, do not need to have the appropriate expertise, and do not need to directly control it (Chen, Wu, Zhang, 2010).

(2) Cloud computing is an ideal carrier of learning resources, which can store and share various digital learning resources almost without limitation. On the one hand, learning resources can be collected and acquired through the Internet of Things (IoT) to form an extensive learning resource library, the intelligent algorithm platform and basic data platform can be used to analyze and make decisions on learning resources, thus promoting the improvement of learners' critical thinking, the development of learning ability and the stimulation of their creative potential.

4) Ubiquitous middle platform. The smart middle platform (Zhongtai) is the most important component of the ubiquitous smart learning space, which is the engine of all smart learning activities, and the root of learning environment. Jonathan Michael

Spector (Zhang. 2019) argues that the general requirement for determining a smart learning environment is to use certain identified environmental characteristics as a basis for making a discernment and realization. To this end, “Zhongtai” has been adopted so that smart learning environments can be measured, carefully customized, discarded, and new technologies adopted.

To achieve such a characteristic demand, the strategy we adopt is to establish a smart middle platform (Zhongtai). Because it is to build a flexible and rapid response to changes in the architecture, can quickly realize the needs proposed by users, avoid duplication of construction, to achieve the purpose of improving efficiency. It can truly achieve a continuous docking of its own capabilities and learners’ needs. It can usually be divided into three levels: learning middle platform, technology middle platform and data middle platform.

(1) Learning Middle Platform: Learning services combine the public needs of learning into services, such as schools, teachers, students, enrollment, employment, teaching, exams, grades, certificates, graduation. These public learning are combined into a unified learning service for each learning unit.

(2) Technology Middle Platform. Basic services are usually technology-oriented underlying services, including interaction engine, intelligence engine, build engine and security engine, etc. These underlying services are usually not very relevant to learning and are functions that every application needs to use.

(3) Data Middle Platform. It includes data collection, data processing, data algorithms and analysis, reporting, and data governance.

5) Ubiquitous applications. It is a set of front-end applications.

(1) Build basic applications through the Zhongtai. Basic applications are the basic functional modules that stakeholders are bound to use, including learning modules, smart modules, teaching modules, management modules, service modules and resource modules. Learning space builders can make trade-offs according to their needs, so that they can use these modules to build or rebuilt a space that meets actual needs, such as a space for primary and secondary schools, universities, and factories, etc.

(2) Build ubiquitous applications with. Multi-experience Development Platforms (MXDPs) are tools for rapid development of cross-platform applications that highlight front-end development capabilities. It is generally used to develop cross-platform/cross-device applications while ensuring a consistent user experience across web, mobile, wearable, conversational and immerse touchpoints. The integration of suitable MXDPs can help USLS realize the rapid rebuilding and development of new applications.

(3) Constituent Elements

Based on the connotation of ubiquitous smart learning spaces, and with reference to existing studies, we identify the core elements of ubiquitous smart learning spaces as four sub spaces, including application space for learning stakeholders, symbiosis space for learning behaviors, digital space for resources, and technology space for maintenance. Figure 5.4 gives the components UML deployment diagrams of the ubiquitous smart learning space and their interrelationships.

Symbiosis space. The ubiquitous smart learning space is an expansion of the traditional learning place, and the two are in essence a seamless unity. The symbiotic space is a learning place for learning stakeholders, and the knowledge acquirer establishes new ways to acquire knowledge with new interactive methods such as virtual-real dialogue, human-machine communication, and intelligent response, and optimizes the learning space through virtual-real interactive feedback, multidimensional data fusion and analysis, and decision iteration to fundamentally promote efficient collaboration in all stages learning activities. Symbiotic space is made of interactive spaces, teaching spaces, creative spaces, exploratory spaces, private spaces, and social

spaces. In contrast to the real physical learning spaces, interactive spaces and teaching spaces correspond to classrooms and meeting rooms, creative spaces and exploratory spaces correspond to laboratories and libraries, private spaces correspond to study rooms and dormitories, and social spaces correspond to internship bases and competition sites.

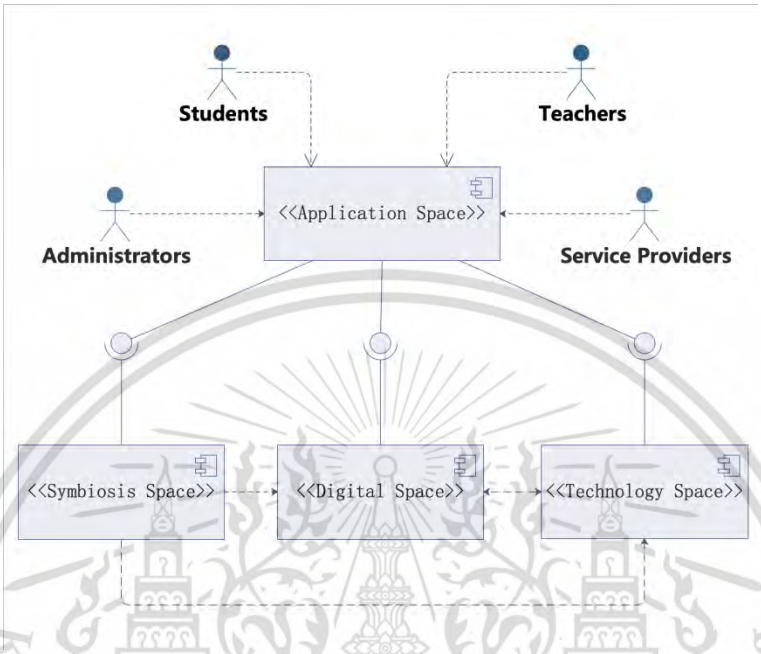

Figure 4.4 Components of The Ubiquitous Smart Learning Space and Their Relationships

Digital space. Data plays an extremely important role in the ubiquitous smart learning space. Data includes not only the personal information data of learners and the behavioral data generated in the learning process, but also their authorized data collected in other fields, including video data, audio data, website data, document data (books, papers, articles, lecture notes, course-ware, lesson plans, exercises, materials, etc.), information data (personal information, behavioral tracks, teaching plans, course schedules, learning results, etc.) and so on. The ubiquitous smart learning space rely on the comprehensive collection of data and various algorithms to realize personalized learning resource recommendation, adaptive learning path and support services with full understanding of learners.

Technology Space. The ubiquitous smart learning space is a place full of technology applications. 1) At the bottom layer, based on the cloud computing platform, various data collection technologies, cloud service technologies, cloud storage technologies, cloud database technologies, and cloud security technologies are integrated to provide learning stakeholders with data, to reflect the real state of learning behavior and management efficiency. 2) In the middle layer, the interactive engine and intelligent engine recommend adaptive learning paths and personalized learning resources for learners through various models. 3) In the application layer, collaborative interaction technology provides a comfortable experience for learners' learning, virtual reality (VR) and augmented reality (AR) technologies support learners to transform knowledge into innovative ideas and practices, big data analysis technology supports analysis and evaluation of learners' learning records, and the building engine can maximize various applications of the space as needed through the building block type

construction technology, providing users with a strong understanding of It provides strong support for the effectiveness of the learning space.

Application Space. The real support services for learning stakeholders in a ubiquitous smart learning space are the various applications, including learning systems, teaching systems, management systems, and service systems. The core application of the learning space is the learning system, i.e., the application that supports learning, or the guided teaching session (Wu, 2017). The ubiquitous smart learning space emphasizes learner-centeredness, and other learning stakeholders provide support services to learners through teaching systems, management systems and service systems. The services it provides include both direct support for learning (such as online lectures, online documents, online videos, online reviews, etc.) and indirect support for learning (such as learning method consultation, psychological counseling, course management, grade management, etc.), and it also includes support for learning (e.g., intelligent search, intelligent recommendation, health tracking, student loans, etc.). The logic of providing learning support applications is to provide learning support applications in a way that learners are comfortable with, by understanding and exploring the learning needs of ubiquitous learners. Smart learning support applications are the key feature for realizing learner self-directed learning and personalized learning.

4.4.5 Architecture Model of Ubiquitous Smart Learning Space

(1) Construction Principles

1) Focus on systematic, whole-process and modular top-level design

Lifelong learning is the process of realizing human potential through a continuous process of support that inspires and enables people to earn the right to acquire the knowledge, values, skills and understanding they need throughout their lives and to apply them confidently, creatively, and enjoyably in a variety of tasks and environments. The construction of a ubiquitous smart learning space needs to fully consider the characteristics of lifelong learning and provide learners with a smart environment that can support them to learn confidently, creatively, and happily, thus forming an ecology that promotes deep learning. Therefore, the construction of a ubiquitous smart learning space should focus on systematic, whole-process and modular top-level design. Systematization and full process means that the design process of the ubiquitous smart learning space should consider the characteristics and needs of ubiquitous learning, and form an overall design plan that is interrelated, organic and coupled, to realize the full process support for the learning process and thus improve the efficiency of learning. Modularity involves the structural design of the ubiquitous smart learning space, which means that the access to various elements, changes in learner needs, and changes in space functions need to be considered in the design process, and the combination of modules to realize the personalized and changing learning needs of ubiquitous learners.

2) The intelligent combination of various spaces is the core mechanism of construction

In the ubiquitous smart learning space, the intelligent combination of application space, symbiosis space, digital space, and technology space forms an organic system that is both distinctive and interconnected. For example, the docking of symbiosis space and technology space can provide learners with adaptive learning paths; the docking of symbiosis space, digital space and application space can better support learners' thinking, dialogue, practice, and innovation in the learning process, thus forming a spatial continuum that supports students' lifelong learning. The intelligent combination of various spaces not only involves the full integration between various systems, but also emphasizes the support for the professional competence and personal literacy

development of the ubiquitous learners, and implies the effective integration of existing platforms, technologies, resources, and tools.

3) Focus on the integration of learning model s and learning spaces

On the one hand, learners' learning participation requires the learning space to provide them with a flexible and convenient learning environment, and through the seamless connection of learning models, learning resources, support technologies and the learning space, the effective connection between various elements and different systems is realized, thus forming a complete intelligent learning support system, and promoting the occurrence of deep learning. On the other hand, to form an open, compatible, and integrated learning environment, the ubiquitous smart learning space needs to fully consider the characteristics of ubiquitous learners in the design of the learning model, so that it can reach deep integration and interaction with the physical learning space, thus better supporting the generation of learners' inspiration and creativity.

4) Emphasis on the integrated application of cloud computing and big data

Cloud computing as a computing platform and big data as a carrier to communicate the physical environment, symbolic environment, and human feedback, contains the practical value of more rational understanding of the nature and function of education, understanding the learning process and psychological world, improving the organization of learning, and providing humanized education. Without cloud computing and big data, there is no way to talk about the ubiquitous smart learning space. Therefore, the construction of ubiquitous smart learning space should focus on the integrated application of cloud computing and big data, which not only includes data storage, data collection, data cleaning, data analysis and other data management-oriented applications, but also includes adaptive learning and learning analysis applications based on big data. The flow and use of data in the ubiquitous smart learning space provides the underlying support for the function of the space to realize a flexible and diverse learning environment, thus enhancing the learning experience and learning performance of learners.

(2) Architecture Model

Through the analysis of the components, functional positioning, and construction principles of the ubiquitous smart learning space, we can find that promoting learner participation is the fundamental starting point of the construction of the ubiquitous smart learning space, and its construction elements, learner characteristics and learning models are the basis for realizing smart learning. The flow of data, the integration of various building elements, and the synergy of various learning models are the keys to its construction, and cloud computing and big data are the basic guarantees for its construction.

The ubiquitous smart learning space architecture model consists of seven layers, from the bottom to up: ubiquitous network, cloud computing infrastructure, intelligent algorithm and data infrastructure platform, smart middle platform, application expansion, smart terminals and learning stakeholders, as shown in Figure 4.5.

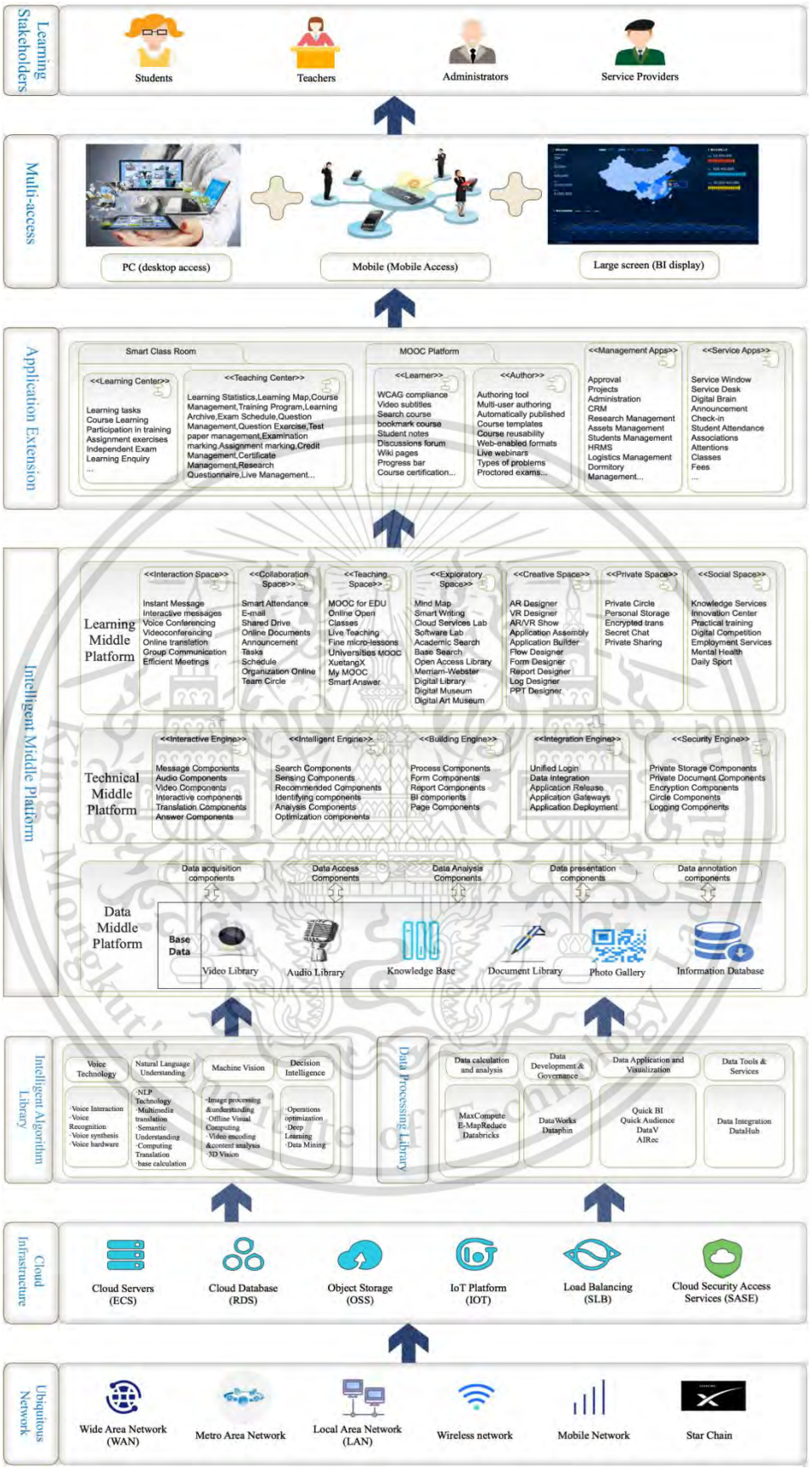

Figure 4.5 Ubiquitous Smart Learning Space Architecture Model

Ubiquitous network provides the possibility of pervasive computing, online connectivity, communication, and information exchange real time, it is the key supporting technology to realize the seamless connection between physical space and virtual space as well as learning-related stakeholders.

Cloud computing infrastructure. Cloud services provide the environment for intelligent computing. Cloud storage provides support for big data applications, and cloud security is the technical guarantee for safe operation of learning spaces.

Intelligent algorithm and data base library. The intelligent algorithm library components are the core of the technology space and is the key element to achieve the goal of intelligence. The data base library components can intelligently analyze and reason about the learning needs of learners, explore the potential learning interests of learners, comprehensively and objectively evaluate the development of learners, and accurately grasp the common characteristics of the learning community.

Smart Middle Platform. It is composed of learning middle platform, technology middle platform and data middle platform, and these middle platforms correspond to the symbiosis space, technology space and digital space pan in the smart learning space.

1) The Learning Middle Platform is a direct platform for collaboration, interaction and interaction among learning stakeholders, and a concrete presentation of the application space, combining public learning functions into a unified learning service for building various learning systems in the smart learning space.

2) The Technology Middle Platform is a technology-oriented basic service, including interaction engine, intelligence engine, build engine, integration engine, and security engine, etc. These engines are the tools for system improvement and expansion.

3) The Data Middle Platform has data parts such as video data, audio data, website data, document data and information data, and covers functional parts such as data collection, data processing, data algorithms and analysis, reporting and data governance, which are the basic support of the intelligent middle platform.

Application Expansion. Application expansion corresponds to the application space, which is a set of application systems., such as learning applications, teaching applications, management applications and service applications, etc., and it is deployed on top of the collaboration platform, is an important support for truly realizing self-directed learning and personalized learning for learners.

Smart terminals. The intelligent terminal of the ubiquitous smart learning space mainly consists of three types of terminals, namely the PC terminal for desktop access, the mobile terminal for mobile access and the large screen terminal for BI display, which can fully meet the needs of learning stakeholders to access the learning space.

Learning stakeholders. Learning stakeholders are composed of learners (students), educators (teachers), administrators, and service providers. Learning stakeholders collaborate and interact with each other.

4.5 Result of Research Question Three and Four-Analysis of Satisfaction and Effect of Ubiquitous Smart Learning Environment

The ubiquitous smart learning space aims to uses technology to enhance and develop learners' learning skills and improve their recognition. Under the guidance of the concept of smart education, the ubiquitous and smart features of the ubiquitous smart learning are certified by the support of multiple learning methods. This chapter focuses on the realization strategy of ubiquitous smart learning activities and its satisfaction and efficiency.

4.5.1 User Expected Experience for Ubiquitous Smart Learning Activities in Ubiquitous Smart Learning Environment

Ubiquitous smart learning environment support learners obtain learning resources on demand, carry out learning activities flexibly and freely, and quickly build knowledge networks and interpersonal networks, are highlighted in the following aspects.

(1) Personalized learning

It provides learners with personalized learning resources, learning tools and learning services that they need now or have potential needs and records their growth. It allows learners to receive one-on-one personalized service from teachers or help learners to aromatically form a learning community with the same learning needs and interests for in-depth interaction on a particular issue.

(2) Learn efficiently

In the process, learners get the latest learning resources by resource subscription and intelligent pushing. Leaning space can anticipate the potential learning needs of learners in advance by means of context-awareness and data mining, and automatically push resources to learners, saving their time in blindly searching for materials. In addition, leaning space provides conditions for learners to apply their knowledge, for example, the practical training platform allows learners to experiment and validate using classic experimental cases and data sets from AI and data science-related majors.

(3) Immersive learning

Leaning is perceptual, personalized, adaptive, and widespread, allowing learners to become more engaged, relaxed, and immersed in their learning. The perceptual and personalized features give learners a sense of the environment understands me, learning becomes enjoyable, and can act as a learning companion and engage in a natural dialogue with learners. For example, learners can create poems through intelligent writing. Learners can also interact with learners from different countries and languages, create a text together online, and more. The interplay between the learner and the environment makes ubiquitous smart learning more immersive. Adaptability and ubiquity make the learning process smoother and more accessible, ensuring that the learner's motivation does not diminish as the learning environment changes. Immersive and ubiquitous smart learning facilitates learners to get rid of the shackles of technology and focus more on the learning itself.

(4) Natural Learning

Natural learning fully satisfies learners' individual needs, preferences, styles, and interests, and allows learners to learn in a more self-directed way in a natural (not externally controlled) learning environment. The naturalness of ubiquitous smart learning is manifested in the learning content, learning scenarios, and intelligent technologies. The learning contents provided in ubiquitous smart learning are close to real life and have practical significance, and such natural learning contents are more likely to stimulate learners' interest; ubiquitous smart learning can occur not only in smart classrooms and smart campuses, but also in libraries, museums, communities, shopping malls and other social places, which can be seamlessly connected through ubiquitous networks to realize the continuity of the learning process. Ubiquitous smart learning requires a variety of intelligent technology support, but these technologies are invisible to learners and will not be noticed by them, so technology will not become an obstacle for learners to carry out ubiquitous smart learning.

(5) Continuous Learning

It enables learners to constantly seek out new knowledge, develop new abilities and achieve new goals. The development of continuous learning requires a strong integration of the student's own will and learning environment. In the learning process,

learners can better understand their own learning characteristics and accurately find their own learning goals, thus stimulating the desire and motivation for continuous learning. Personalized learning resources, real-time feedback, multiple evaluations, and a harmonious atmosphere from all sources will provide external guarantees for continuous learning. The integration of formal and informal learning, independent and collaborative learning, makes learning activities more flexible.

4.5.2 Key Learning Models in Ubiquitous Smart Learning Environment

The ubiquitous smart learning space is learner-centered and supports multiple learning models, mainly supports independent learning, collaborative learning, immerse learning model, creative learning model and critical thinking learning model.

(1) Independent Learning Model

Independent learning model that allows learners to independently select learning resources, tools, and services, learners are self-help in the learning process. Teachers provide learning guidance and consulting services to help learners get the resources.

The learning resources come mainly from the teaching space and the social space. The implementation process of the independent learning model includes defining learning goals, executing learning plans, access to learning outcomes, and evaluating learning outcomes, and the activity diagram of the independent learning model is given in Figure 4.6.

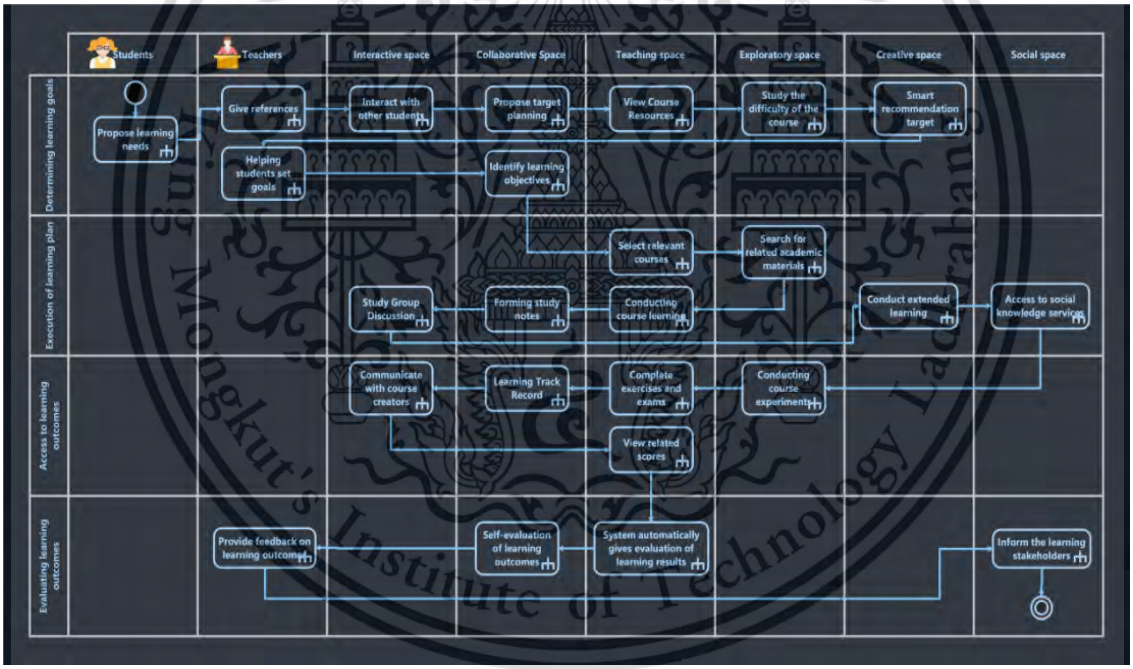

Figure 4.6 Independent Learning Model Activity Diagram

1) Determining learning goals

Learners check their own courses, grades, and credits, etc. through the collaborative space and the transfer space, and then, according to their current needs and after communicating with teachers and classmates, clarify their learning goals and make learning plans with the massive course resources. The learning goals can be decided by the learners themselves through search, discussion, and consultation, etc. At the same time, the learners can also inform the AI tools in the USLS creative space about their goals, so that the intelligent recommendations can help the learners complete some

basic work (such as analysis of the reasonableness of the goals and pre-finding of learning resources, etc.).

2) Implementation of learning plan

Learners take the learning plan as the center, carefully select learning courses and resources, carry out independent learning through the tools provided by the teaching space (such as smart classroom, MOOC classroom and micro-lesson, etc.) and the tools provided by the social space (such as knowledge services, etc.), form study notes in the collaborative space, start group discussions in the interactive space, carry out course experiments in the exploratory space, expand learning in the creative space, etc., and make full use of the learning tools provided by USLS to achieve effective learning.

3) Access to learning outcomes

Learning outcomes include learning courses and resources acquired by learners in the learning process, formed programs, reports, and works. The resources of learners' successive independent learning are automatically formed into learning maps through the teaching space (smart classroom). The various programs, reports, assignments, posts, questions, as well as works, grades and credits generated by the learning process are stored in the learner's learning file as generative resources. The process of viewing learning gains also allows learners to connect with the creators and collaborators of courses and resources, as well as learners who have adopted the same resources, for in-depth communication and interaction, facilitating the social academic relationships among learners.

4) Evaluation of learning outcomes

The evaluation of independent learning includes two parts: self-evaluation and systematic evaluation. Learners can use the evaluation scale provided by USLS to conduct self-evaluation based on their learning performance and can also express their personal opinions through learning circles, project groups, and learning groups; in addition, the Smart Classroom will analyze and count the learners' course learning history, learning hours, examination results, and credit acquisition, and provide learners with learning evaluation of this learning or previous learning then analysis and give a report. The system evaluation is a quantitative and objective evaluation with horizontal comparison, learner can compare your learning performance with that of other learners and find your own gaps and shortcomings through comparison.

(2) Collaborative Learning Model

Collaborative learning refers to the collaborative learning of learners in groups or teams, which can be composed of students in the same class, learning partners with the same learning goals or similar learning interests, or learners in the same open place (e.g., internship sites, shopping malls, communities, etc.). The group formation and project clusters of USLS support large-scale group collaborative learning. The implementation process includes flexible grouping and unified goals, define tasks and form plans, intelligent division of learning and cooperation, and shared results and collective evaluation, and the activity diagram of the collaborative learning model is given in Figure 4.7.

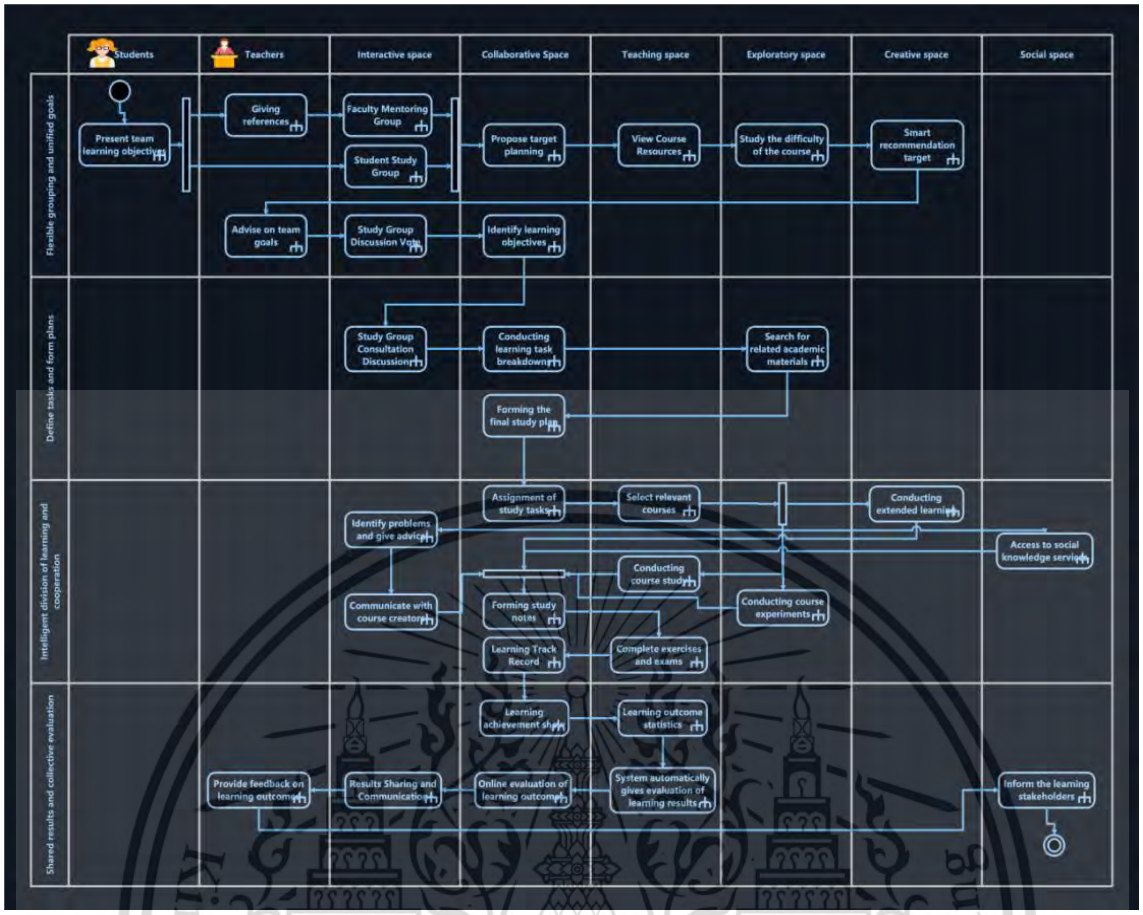

Figure 4.7 Activity Diagram of Collaborative Learning Model

1) Flexible grouping and unified goals

USLS provides flexible group construction methods, which can automatically form groups according to the organizational structure, or freely combine according to learning needs or project demands or interests, etc. Especially, instructors or experts and scholars can be pulled into the groups, which solves the obstacles of traditional collaborative learning in the grouping space and the grouping difficulties caused by the complexity of learners' needs and characteristics, and can achieve more efficient, scientific, and reasonable grouping.

After the group division is completed, the learning objectives of the group need to be unified. Due to the complexity and large scale of groups, it is difficult to form consistent learning goals among them. Therefore, USLS collaborative space provides methods such as mind mapping, online documents, and project design, and then form unified group learning objectives through the function of video meeting and member voting in the interactive space.

2) Define tasks and form plans

USLS presents all planned activities to learners in a visual way. The tasks and plans for group collaboration are dynamically adjusted according to the learning situation, and each group member can dynamically track the activities and give real-time feedback.

3) Intelligent division of learning and cooperation

Group collaborative learning focuses on process collaboration, learning stakeholders and learning communities. The task division of group collaborative learning is based on each learner's personality characteristics, learning needs, abilities,

and qualities, as well as the group's learning goals and plans. Various collaborative learning activities, such as voting, discussion, investigation, video meeting, project schedule, drawing concept maps, etc. can be carried out during the learning process, and members can find problems and give relevant opinions in the collaborative process in time.

4) Shared results and collective evaluation

Group members will produce many learning outcomes, such as research reports, learning course ware, experience reflections, solutions, in the process of completing their respective responsible tasks. Through the group sharing function of USLS, members can share the learning results with each other and exchange learning experiences and tips among the groups. The evaluation of group learning results adopts online collective evaluation, each learner participates in the evaluation process, carrying out self-evaluation, peer evaluation and group evaluation (evaluation of group collaboration). USLS also analyzes the process information of group collaboration and gives quantitative evaluation results based on relevant evaluation models.

(3) Situated Learning Model

There are two types of situated learning: formal learning based on a defined topic, and informal learning without a specific topic. Learners enter the two types of situated learning in different states and with different learning outcomes. The former is based on a certain task, with a clear learning goal before it is carried out, and the learning is carried out with a problem in the context; the latter is initiated by the learners themselves according to their current needs and interests, and they enter the learning situation in a relaxed and natural way.

A) The formal learning implementation process of the situated learning model includes define the exploratory task, access to places of exploration, access to exploratory information, aggregate exploratory information, and forming the results of the exploratory, and the formal learning activity diagram of the situated learning model is given in Figure4.8

1) Define the exploratory task.

During formal learning, learners enter the situation with clear learning objectives and tasks, and propose learning objectives at USLS, then learners decide independently through search, discussion, and consultation, etc. At the same time, learners can also inform the AI tools in the creative space of USLS about their objectives, to help learners complete some basic work in the early stage (such as analysis of the rationality of objectives, pre-finding of learning resources, etc.) through intelligent recommendations, and determine learning objectives and tasks after the combination of the two.

2) Access to places of exploration.

USLS provides learners with opportunities for hands-on exploration, allowing them to learn and explore according to defined learning objectives and tasks, to engage in hands-on activities, and to enrich their learning knowledge.

3) Access to exploratory information.

Based on the learning that has been carried out, USLS forms learners' learning notes, records learning tracks, obtains learning results, collects experimental data, and obtains knowledge service results, etc.

4) Aggregate exploratory information.

USLS forms learning summaries and reports based on the achieved learning outcomes, obtains learning statistics, and performs intelligent analysis of learning outcomes to obtain final learning results.

5) Forming the results of the exploratory.

After the learning tasks are completed, USLS can conduct course-related comprehensive assessments. Learners can use or design assessment measures for self-

evaluation, resulting in comprehensive assessment results and sharing the results of the discussion inquiry with classmates. USLS will provide timely feedback to learners on the assessment results in a visual way to help them revise their learning progress.

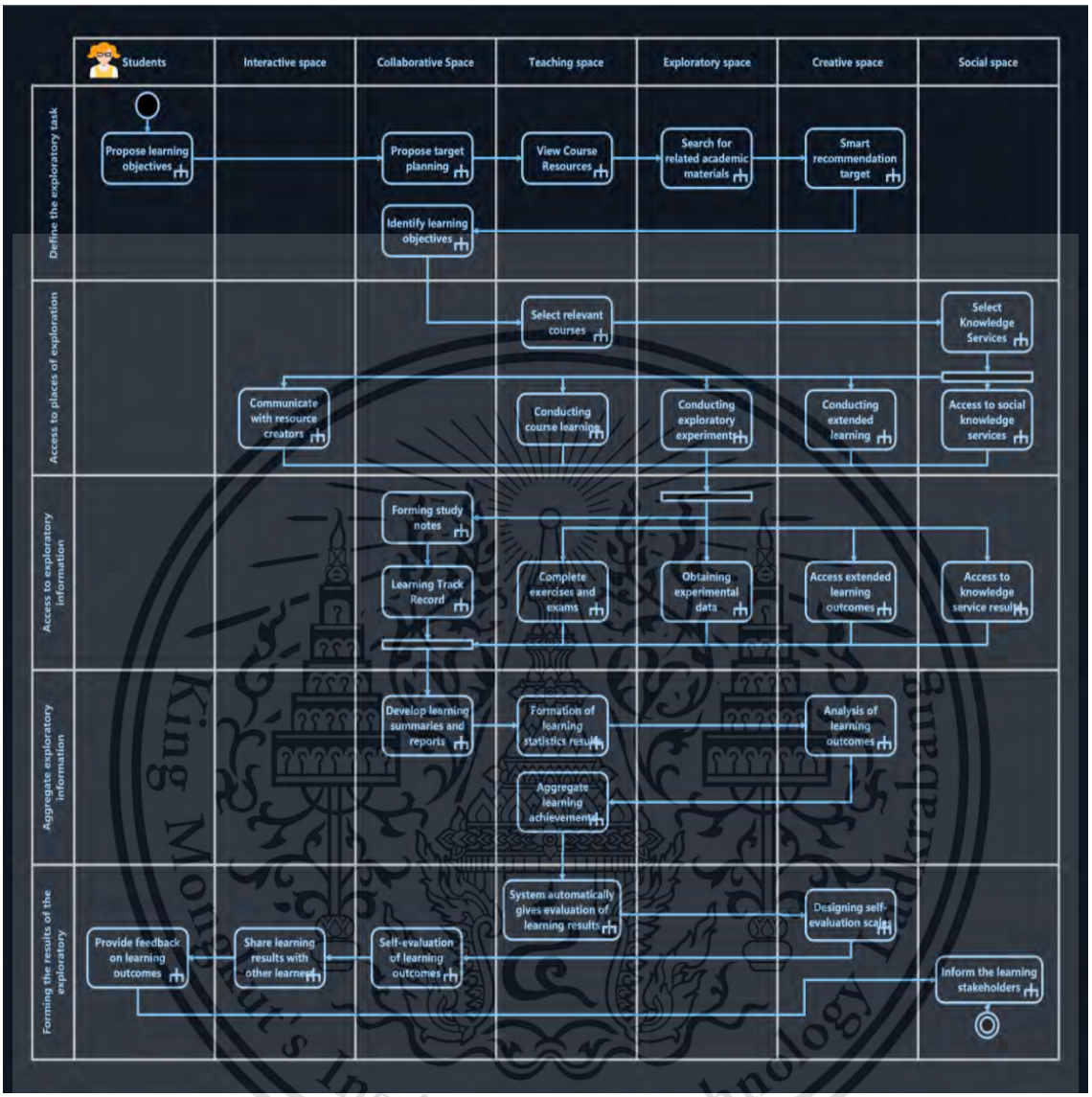

Figure 4.8 The Formal Learning Activity Diagram of The Situated Learning Model

B) Informal situated learning is one of the effective ways to develop students' innovation ability and cultivate their interest in learning. The USLS provides a more intelligent, personalized, and contextualized learning place for learners to carry out informal situated learning. The informal learning implementation process of the situated learning model includes exploring interest in learning content, access to places of exploration, acquiring inquiry information, summarizing inquiry information and formation of re-learning mechanism.

1) Exploring interest in learning content.

Learners search for objectives of interest through the curriculum search in the teaching space, the resource search in the exploratory space and the knowledge search in the social space, while learners can also inform the AI tools in the USLS creative space of the objective information, push personalized learning resources, and

intelligently plan learning paths, and determine learning objectives and tasks after the combination of the two.

2) Access to places of exploration.

USLS provides learners with opportunities for hands-on exploration, allowing them to learn and explore according to defined learning objectives and tasks, to engage in hands-on activities, and to enrich their learning knowledge.

3) Access to exploratory information.

Based on the learning that has been carried out, USLS forms learners' learning notes, records learning trajectories, obtains learning results, collects experimental data, and obtains knowledge service results, etc.

4) Aggregate exploratory information.

USLS forms learning summaries and reports based on the achieved learning outcomes, obtains learning statistics, and performs intelligent analysis of learning outcomes to obtain final learning results.

5) Formation of re-learning mechanism.

USLS becomes a learning companion and "guide" for learners, stimulating their interest and desire to learn, encouraging them to discover knowledge through inquiry, and solving problems and questions on their own. In the process of independent inquiry, USLS also automatically recommends to learners learning partners who may be interested or in similar positions, encourages learners to carry out communication activities with each other, and builds interpersonal networks to improve social interaction skills.

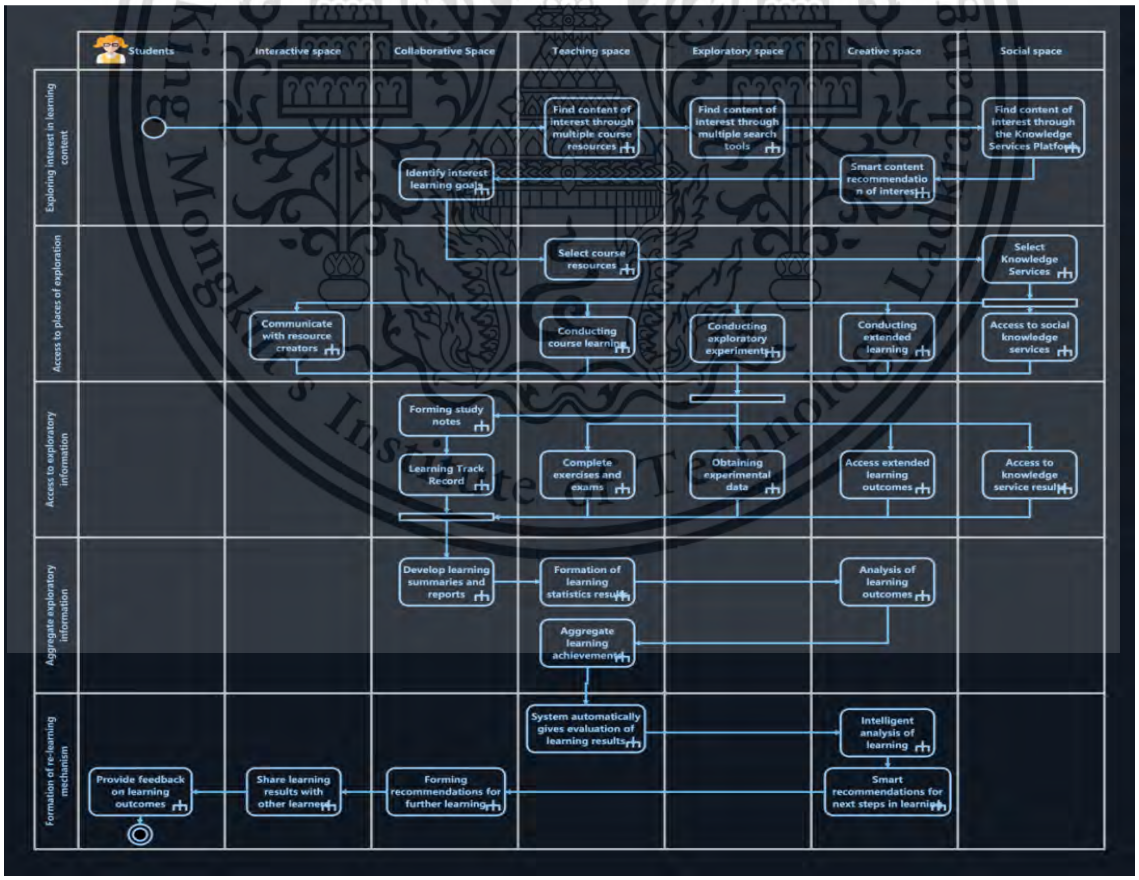

Figure 4.9 The Informal Learning Activity Diagram of The Situated Learning Model

(4) Creative Learning Model

Maker is a class of people who make creativity their core competency. Creative learning is the transplantation of the " maker" spirit in the field of learning. It can improve learners' theoretical knowledge and practical ability, their ability to analyze and solve problems, and their ability to develop reverse thinking, critical thinking, and the habit of innovation (Guo, Zheng, Yang, 2014). The maturity of VR/AR design, MXDPs and 3D printing has made creative learning possible. The creative learning model contains four main components in USLS: specialized learning, creative ideas, design and development, and practical applications.

1)Specialized Learning.

Learners need to learn the relevant theories to have a certain basic knowledge, and then actually examine the real situation to find the shortcomings or explore the new market needs, and then analyze the problem through intelligent technology and tools to stimulate creativity.

2) Creative ideas.

Creative conceptualization is a key part of creative learning. Having a reasonable conceptualization is the keyway to produce products that are both innovative and practical, and reasonable creativity is based on thematic learning. Insert online documents such as brain diagram, road map, process circle, and knowledge base in the resources private and social space to make more idea, the brain map, the route circle, and the flow chart all support team members to collaborate in real time, and the team collaboration is more efficient and convenient.

3) Design and development.

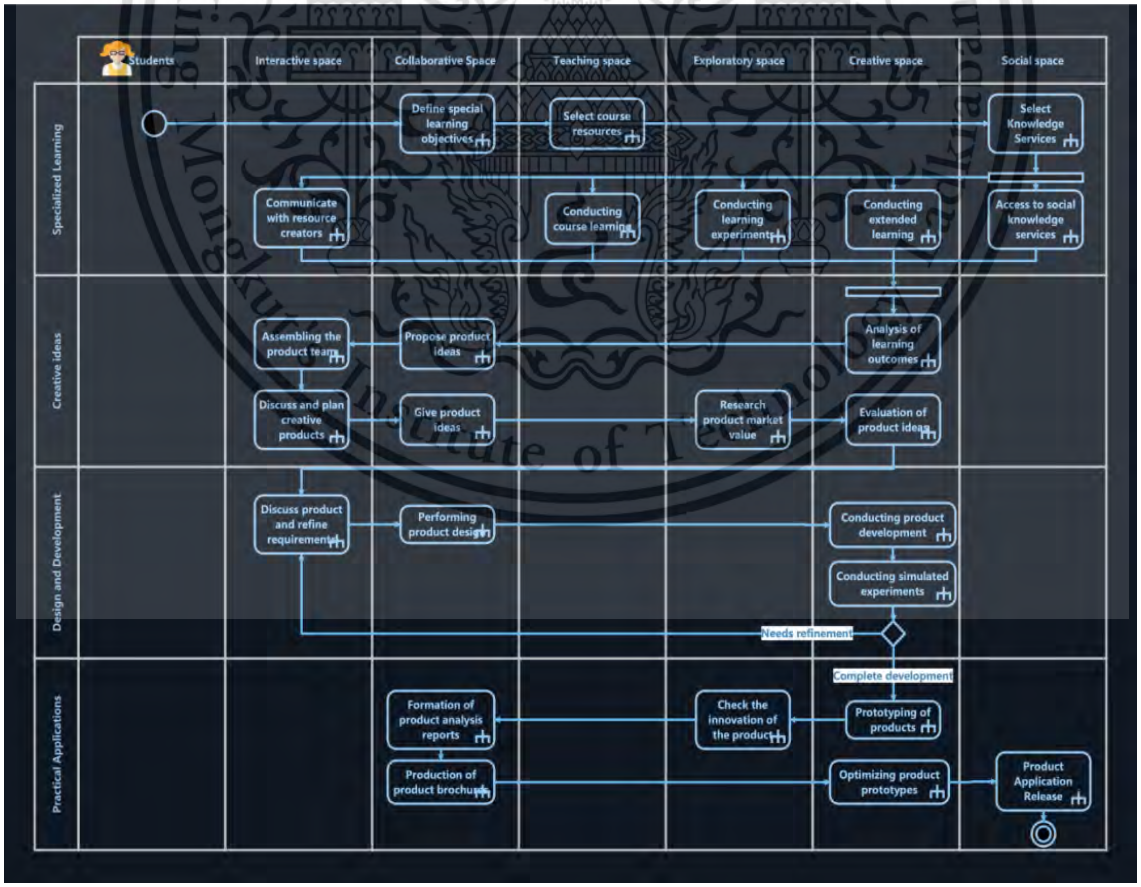

Figure 4.10 The Activity Diagram of The Creative Learning Model

Learners need to convert ideas into practical and actionable design solutions. Through various means such as data collection through smart environment, online contact and consultation with experts, information related to the design and realization of the idea is collected to form a design solution. Then, 3D modeling, and simulation experiments are conducted through digital design tools, and the design plan is continuously improved in the simulation experiments.

4) Practical applications.

The designed models are prototyped by rapid prototyping tools (such as 3D printers) and applied in practice to test the rationality of the ideas and the practical application value of the products.

(5) Critical Thinking Learning Model

The FRISCO conceptual model is a core part of Robert. H. Ennis' critical thinking theory. Ennis divides critical thinking into two parts: skills and awareness, and the FRISCO model theory is an important viewpoint, which considers critical thinking ability include mainly Focus, Reasons, Inference, Situation, Clarity, and Overview. Inference, Situation, Clarity, and Overview, which provide structural elements to inform the design of learning activities.

Problem-Based Learning (PBL) is a model that places learning in complex, meaningful problem situations, where students work in groups to solve problems, learn the knowledge behind the problems, develop problem-solving skills, and develop independent and lifelong learning skills. Barrows (Barrows, H.S. 1980) was the first to summarize and refine problem-based learning activities to: organizing learning groups, creating problems, executing problems, presenting results, and reflecting on evaluation. With the advancement of research and practice, Hmelo-Silver adapted and modified Barrows' approach and proposed a seven-step learning process (Hmelo-Silver, C. E. 2004)): Problem Scenario, Identify Facts, Generate Hypotheses, Identify Knowledge Deficiencies, Apply New Knowledge, Abstraction, and Evaluation.

The research compare and analyze Ennis' FRISCO model theory with the problem-based learning model PBL and find that the 6 elements in the FRISCO model correspond to some extent to the 7 links in the problem-based learning model , so it integrated two models then proposed the critical thinking learning model in USLS, which contains 7 aspects: Problem Scenario, Problem Focus, Exploratory Learning, Issue resolution, Results reporting, Reflective evaluation, and Practical application. The new learning model elements add practice application to the FRISCO elements. Figure 6.6 illustrates the activities of the critical thinking learning model.

1) Problem scenario

In problem solving activities that promote the development of critical thinking, both the thinking process and the practice process need to be thought and practiced in specific problem contexts. In problem scenario design, mainly based on 2 principles, first, support the problems which are complex, ill-structured, open-ended, and based on reality and resonate with students' experiences; second, solutions to problems should be enough to use multidisciplinary knowledge, problems should be responsive to a variety of learning strategies and styles and promote the enhancement of students' knowledge and skills.

2) Problem focus

USLS support learner to clarify the problem, formulate the problem, and focus on the nature of the problem. Students and instructors can discuss on the problem and the problem-solving objectives; then formulate a hypothesis means that students must design a feasible solution to the problem.

3) Exploratory learning

In USLS, learners dig in and gain knowledge, share in groups, revise, and synthesize learning, and teachers give students the necessary guidance and collaboration to explore the causes of problems and identify the reasons for their formation based on focusing on the nature of the problem.

4) Issue resolution

USLS enhance learners' skill to draw conclusions from given situations and reasons. Groups can integrate the information gathered by each student and analyze the validity of the information meeting record or daily log, form a preliminary solution to the problem, and to use this solution to solve the problem, but when the problem to be solved is inconsistent with the hypothesis, the problem will be remind to be revised again, thus requiring the ability of learners to focus, explore and reason without distracting factors, and students need to explore learning points on their own when the learning effect is seriously affected by certain lack of knowledge, the space can push resources to them.

5) Results reporting

Each group or group member can use different forms (graphs, data analysis, oral report and PPT, etc.) to report the group's or individual's learning results, so that students can deepen their understanding of the content and construct or reconstruct their cognitive system during the exchange and discussion.

6) Reflective evaluation

USLS support learners assesses the goals of the course and projects progress, to reflect their attitudes and skills, and other aspects of learning. Group members through group communication and discussion to do online teamwork and based on evaluation analysis report.

7) Practical application

Learners can use practical application platform to practice what they have learned, to concretely solve real problems, to verify the validity of the results, and there are different experts in person and robot can offer guidance.

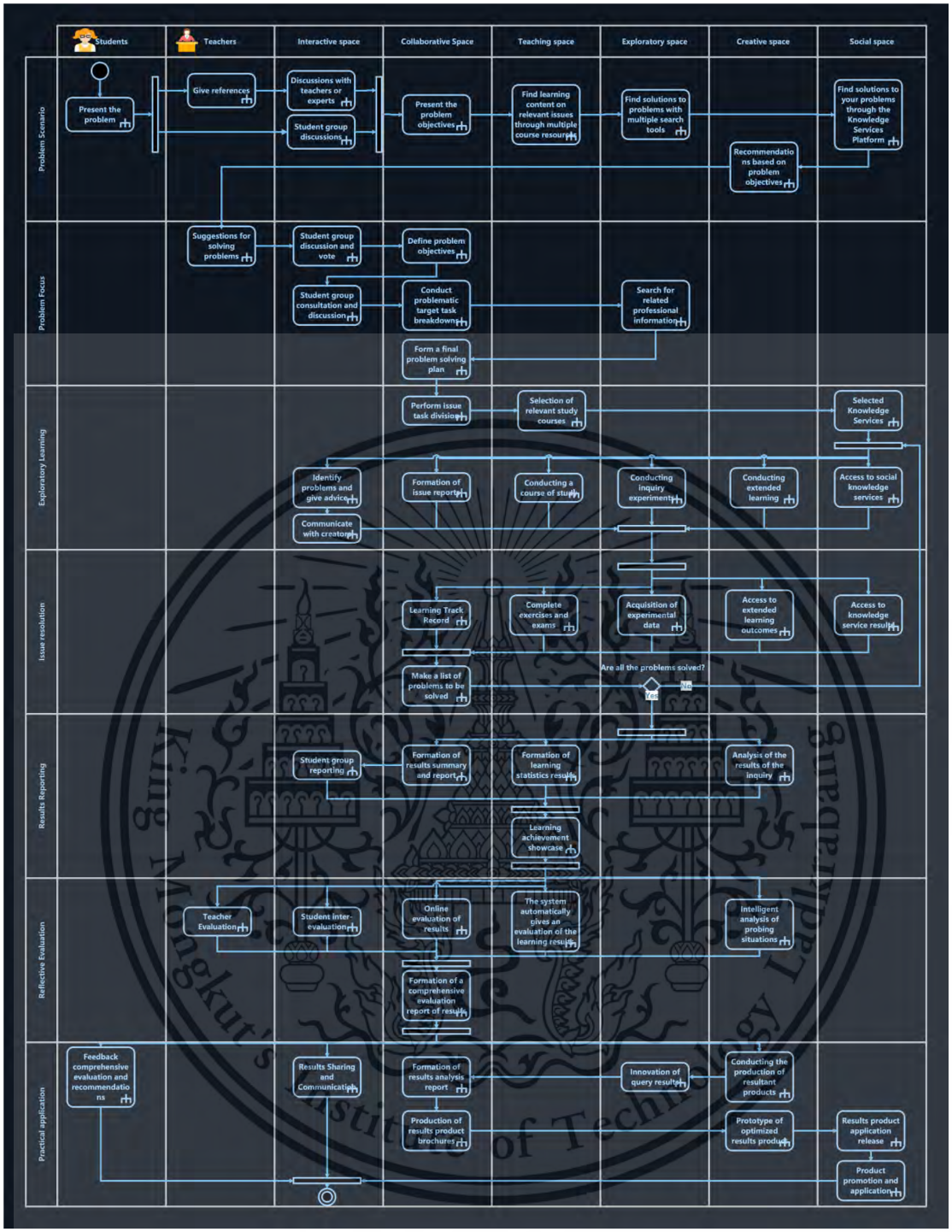

Figure 4.11 Activity Diagram of The Critical Thinking Learning Model

4.5.3 Analysis of User Satisfaction on Learning Environment in USLS

Table 4.11 Descriptive Analysis of The Survey Questionnaire

Items	Mean	Std. Deviation	Meaning
1. Collaborative Learning Environment	**4.57**	**0.43**	**Satisfy**
Digital equipment	4.97	0.18	**Satisfy**
Interaction capability	4.88	0.34	**Satisfy**
Collaboration ability	4.67	0.54	**Satisfy**
Learning resources	4.52	0.65	**Satisfy**
Learning tools	4.79	0.45	**Satisfy**
Intelligent perception	3.80	0.89	**Satisfy**
Comprehensive review	4.35	0.73	**Satisfy**
2. Collaborative Learning Activities	**4.56**	**0.51**	**Satisfy**
Flexible grouping	4.66	0.54	**Satisfy**
Unified goals	4.55	0.62	**Satisfy**
Define tasks	4.75	0.49	**Satisfy**
Form plans	4.48	0.66	**Satisfy**
Intelligent division of learning	4.13	0.80	**Satisfy**
Cooperation	4.62	0.57	**Satisfy**
Shared results	4.86	0.36	**Satisfy**
Collective evaluation	4.41	0.70	**Satisfy**
3. Collaborative Learning Effectiveness	**4.47**	**0.63**	**Satisfy**
Learning content	4.49	0.66	**Satisfy**
Learning motivation	4.45	0.67	**Satisfy**
Learning engagement	4.33	0.75	**Satisfy**
Learning interest	4.53	0.64	**Satisfy**
Favorite level	4.64	0.56	**Satisfy**
Level of effort	4.37	0.73	**Satisfy**

Student satisfaction with “Digital Equipment” was the highest at 4.97, indicating that students can use USLS well on any device, meaning that learning activities can be done at any time and any place.

Students also rated their interaction and collaboration capability at 4.88 and 4.67, which is rare, indicating that USLS provides efficient and convenient support for group interaction. There are many learning tool (rated at 4.79) support student-student interaction, student-teacher interaction, and communication with outside experts and scholars as a basis for effective learning.

In learning activities, students very much like to use mind maps to determine tasks and objectives, sort out, review, and summarize knowledge points. With the help of mind maps, they can sort out scattered and fragmented knowledge into a knowledge tree with a certain logic and organization, which helps students' self-learning and self-inquiry. Online document sharing and edition, task management are also favoring tool for students, which fully demonstrates that USLS provides a good help for collaborative learning.

The highest mean value of learning effectiveness was 4.64 on “Favorite level”. Students participated in the collaboration activity easily and effectively supported by collaboration environment, students can experience sense of ownership of the classroom and importance, so they were very satisfied with the collaboration environment and activities.

From the results, we can also see that the rating of intelligent perception is the lowest, which also indicates that there is still more room for improvement in terms of intelligent perception of learning situations, identification of learner characteristics, intelligent recommendation of appropriate learning resources and smarter learning tools, which is what USLS needs to be further updated and iterated in the future.

At the same time, the interviewed teachers compared the USLS collaborative learning model with the traditional classroom collaboration model. They reached the following consensus.

In terms of teaching effectiveness, collaborative learning activities using the USLS space are a new experience for students, with strong interest in learning and good learning outcomes.

From the point of view of the teaching model, the participation of group members by video or live streaming makes communication between students easy, and the use of students' mobile terminals makes all kinds of communication more effective.

In terms of teaching methods, using teaching tools such as smart classroom, MOOC, and micro-learning, allowing students to record key points through collaborative space mind maps, share course notes with online documents, teachers to explain and instruct through videos, and learning groups to discuss, communicate and ask questions, making students the masters of the classroom and promoting the practice and implementation of a student-oriented, teacher-assisted classroom education concept. “All these strategies help me extend interaction between teachers and learners, The interaction in the traditional classroom is very weak. I don't have time to communicate with so many people, and I don't have the opportunity to understand their needs. Even the most basic "seeing each other" will stop when I leave the classroom. But the interaction of the smart learning environment is not limited to the classroom.”

From the analysis of the results, the intelligent analysis tools are not powerful enough and need to be combined with students' personal characteristics and interests for in-depth analysis, while the results of intelligent recommendations are still relatively simple, and more data need to be collected to form a more complete portrait of students and to integrate more powerful intelligent technologies into teaching practice activities.

In summary, the results show that collaborative learning activities guided by the USLS collaborative learning model significantly contribute to student learning and skills development; teachers and students are more satisfied with the development of collaborative learning activities guided by the model in ubiquitous smart learning space than the collaborative model in traditional classrooms.

4.6 Result of Research Question Four

4.6.1 Experimental Object Selection

In this study, a 20-week experiment was conducted to students in the second semester of the first-year student at big data college in Southwest Forestry University, and 64 students in Computer Science and Technology 2021(1) class.

4.6.2 Activities Scope

The content covered all students' affairs, such as exams, learning activities, teaching and test related to student management.

4.6.3 Activity Design

Experimental class activity design: Students in the experimental class carry out learning and design the software modeling process according to the seven links of problem situation, problem identification, inquiry learning, problem solving, result reporting, reflection and evaluation, and practical application in the activity and whole class need complete a software system modeling, during the process, exams, learning activities, teaching, student management involved in all kinds of stakeholders, including teachers, students, headteachers (present the role of administer), technology service provider.

Correlation analysis was used to investigate the correlations between Truth-Seeking and Open-Mindedness, Analyticity, Systematicity, Self-Confidence, Inquisitiveness, and Maturity, using Pearson's correlation coefficient to indicate the strength of the correlations (see Tables 6.10).

All six items of Truth-Seeking and Open-Mindedness, Analyticity, Systematicity, Self-Confidence, Inquisitiveness, and Maturity showed significant correlations with coefficient values of 0.675, 0.470, 0.493, 0.257, 0.317, and 0.490, respectively, and all correlation coefficient values were greater than 0, implying that Truth-Seeking has a positive relationship with Open-Mindedness, Analyticity, Systematicity, Self-Confidence, Inquisitiveness, and Maturity. Self-Confidence, Inquisitiveness, and Maturity have a positive correlation between a total of six items.

Table 4.12 Correlation Analysis Among the Dimensions of The Scale

	Truth-Seeking	Open-Mindedness	Analyticity	Systematicity	Inquisitiveness	Self-Confidence	Maturity
Truth-Seeking	1						
Open-Mindedness	0.675**	1					
Analyticity	0.470**	0.670**	1				
Systematicity	0.493**	0.623**	0.840**	1			
Inquisitiveness	0.257*	0.544**	0.728**	0.711**	1		
Self-Confidence	0.317*	0.476**	0.741**	0.662**	0.610**	1	
Maturity	0.490**	0.564**	0.541**	0.590**	0.343**	0.445**	1

* p<0.05 ** p<0.01

4.6.3 Results of The Critical Thinking

(1) Pre-and Post-Test Analysis of Critical Thinking

The questionnaires were administered to the learners before and after the implementation of the study. 67 questionnaires were distributed for each of the two tests, and 64 valid questionnaires were returned for each test, with an effective rate of 95.5%. Data were analyzed using Excel software and SPSSAU software to obtain pre- and post-test data on learners' critical thinking tendencies.

Table 4.13 Pre- and post-test statistical analysis of critical thinking

Stage	N of samples	Min.	Max.	Mean	Std. Deviation	P(Bilateral)
Pre-test	64	77	410	239.83	46.58	0.000
Post-test	64	155	412	280.89	34.79	

As can be seen, the mean value of the pre-course critical thinking disposition test of the participants in this study was 239.83, which was in the range of 210-280, indicating that the level of critical thinking disposition of the participants before the implementation of the study was model rate. The mean score of 280.89 on the post-study Critical Thinking Test was in the range of 280-350, which indicates that the level of critical thinking disposition of the study participants was model rate to high after the implementation of the study. From the mean value of the results of the critical thinking disposition test, the overall level of the learners' critical thinking disposition increased significantly before and after the implementation of the study, and the overall critical thinking disposition development of the study participants changed from model rate to model rarely high.

We used paired t-tests to investigate the differences between the pre and post-test data and it can be seen that: the pre and post-test paired data, both show differences ($p<0.05$).

Table 4.14 Paired t test

Items	Paired (M±SD)		Mean difference (Post-test - Pre-test)	t	p
	Post-test Mean	Pre-test Mean			
Post-test Paired Pre-test	280.89±34.79	239.83±46.58	41.06	23.301	0.000**

* $p<0.05$ ** $p<0.01$

Specific analysis shows that the data from the post-test and the pre-test show a significance at the 0.01 level ($t=23.301$, $p=0.000$), and the mean of the post-test (280.89), was significantly higher than the mean of the pre-test (239.83), indicating an extremely significant difference in the learners' tendency to think critically before and after the implementation of the study.

By dividing the learners' scores on the pre-test and post-test of critical thinking tendency into score intervals and categorizing them into corresponding level intervals, the reasons for improvement have been found by comparing the number of learners in each score interval on the pre-test with the number of learners in each score interval on the post-test.

Table 4.15 Percentage of Scores in Each Interval of Pre and Posttests of Critical Thinking

Stage	N of samples	Number and percentage of scores			
		Strong （>350）	Upper medium （280-350）	Medium （210-280）	Weak and none （<210）
Pre-test	64	2（3%）	5（8%）	45（70%）	12（18%）
Post-test	64	3（5%）	27（42%）	33（52%）	1（1%）

From the data in the table, it can be found that: the learners' critical thinking tendency levels before the implementation of the study were mostly concentrated

between 210-280 points, mostly at the medium level, 12 of them at the weak level, 45 at the medium level, and 7 at the medium-upper level. Through the implementation of the learning activities, the overall critical thinking level of the learners changed significantly, in the post-test data, the week level of 12 learners improved significantly after the implementation of the activities, and the medium level of 22 learners increased to an upper intermediate level. The analysis of the above data clearly shows that the learners' critical thinking tendencies increased significantly. This indicates that USLS's is effective in promoting the development of learners' critical thinking tendencies.

(2) Results of The Critical Thinking Experiment

Table 4.16 Results of Paired T-Test Analysis for Each Dimension of Critical Thinking Disposition

Items		Paired (M±SD)		Mean difference (Paired1-Paired2)	t	p
		Paired1	Paired2			
Truth-Seeking (Post-test)	Truth-Seeking (Pre-test)	42.33±7.29	32.36±8.80	9.97	31.573	0.000**
Open-Mindedness (Post-test)	Open-Mindedness (Pre-test)	36.77±5.90	32.19±8.42	4.58	10.093	0.000**
Analyticity (Post-test)	Analyticity (Pre-test)	45.00±5.65	35.47±7.48	9.53	31.049	0.000**
Systematicity (Post-test)	Systematicity (Pre-test)	38.83±6.36	35.78±8.05	3.05	10.074	0.000**
Inquisitiveness (Post-test)	Inquisitiveness (Pre-test)	42.95±6.45	36.23±8.59	6.72	14.277	0.000**
Self-Confidence (Post-test)	Self-Confidence (Pre-test)	41.45±6.31	36.95±8.54	4.50	10.379	0.000**
Maturity (Post-test)	Maturity (Pre-test)	33.56±7.99	30.84±9.41	2.72	5.658	0.000**

* p<0.05 ** p<0.01

From the paired-sample t-tests of the dimensions of learners' critical thinking disposition on the pre- and post-tests (see Tables 4.16), among the seven dimensions of critical thinking disposition on the pre- and post-tests: the Truth-Seeking dimension and the Analyticity dimension had highly significant differences with a very large increase; followed by the Self-Confidence dimension and the Inquisitiveness dimension, and then the Open-Mindedness dimension and the Systematicity ability dimension.

Truth-Seeking, the Analyticity, the Inquisitiveness, and the Self-Confidence of the learners increased hierarchically, and the mean values of the test scores of these three dimensions increased from the model rate level (30-40 range) to the model rarely high level (40-50 range). The mean level of the Analyticity reached 45 points.

The above analysis shows that the ubiquitous smart learning space can improve learners' critical thinking ability.

4.6.4 Analysis of Experimental Results of Collaborative Learning

The subjects, activity topics, and process of the collaborative learning experiment were the same as those of the critical thinking experiment, and the scale was the international professional instrument "Five Barriers to Teamwork". 67 questionnaires were distributed, and 64 valid test questionnaires were returned, with an effective rate of 95.5%, and the scale passed the reliability and validity assessment for use in this study.

(1) Experimental Results of Collaboration

We used paired t-tests to investigate the variability of the pre and post test data. The results of the teamwork ability experiment are shown in Table 4.17.

Table 4.17 Paired T Test on Teamwork Ability

Items	Paired (M±SD)		Mean difference (Paired1-Paired2)	t	p
	Paired1	Paired2			
The first obstacle (Pre-test) Paired The first obstacle (Post-test)	6.13±1.87	6.89±1.86	-0.77	-3.53	0.00**
The second obstacle (Pre-test) Paired The second obstacle (Post-test)	6.11±1.89	7.14±1.91	-1.03	-4.48	0.00**
The third obstacle (Pre-test) Paired The third obstacle (Post-test)	6.30±2.01	7.23±1.96	-0.94	-3.88	0.00**
The fourth obstacle (Pre-test) Paired The fourth obstacle (Post-test)	6.28±2.00	7.02±1.94	-0.73	-3.11	0.00**
The fifth obstacle (Pre-test) Paired The fifth obstacle (Post-test)	5.80±1.81	6.69±1.88	-0.89	3.96	0.00**

* $p<0.05$ ** $p<0.01$

From the above table, a total of five paired data groups will show variability ($p<0.05$). Specific analysis shows that.

The first obstacle (pre-test) and the first obstacle (post-test) showed a significant level of 0.01 (t=-3.532, p=0.000), as well as a specific comparison of differences can be seen that the mean of the first obstacle (pre-test) (6.12), will be significantly lower than the mean of the first obstacle (post-test) (6.89).

The second obstacle (pre-test) and the second obstacle (post-test) showed a significance at the 0.01 level (t=-4.477, p=0.000), as well as a specific comparison of the differences can be seen that the mean of the second obstacle (pre-test) (6.11), will be significantly lower than the mean of the second obstacle (post-test) (7.14).

The third obstacle (pre-test) and the third obstacle (post-test) showed a 0.01 level of significance between them (t=-3.877, p=0.000), as well as specific comparative differences that show that the mean of the third obstacle (pre-test) (6.30), would be significantly lower than the mean of the third obstacle (post-test) (7.23).

The fourth obstacle (pre-test) and the fourth obstacle (post-test) showed a 0.01 level of significance between them (t=-3.112, p=0.000), as well as specific comparative differences that show that the mean of the fourth obstacle (pre-test) (6.28), would be significantly lower than the mean of the fourth obstacle (post-test) (7.02).

The fifth obstacle (pre-test) and the fifth obstacle (post-test) showed a 0.01 level of significance between them (t=-3.957, p=0.000), as well as a specific comparison difference that shows that the mean of the fifth obstacle (pre-test) (5.80), would be significantly lower than the mean of the fifth obstacle (post-test) (6.69).

In total, all five sets of paired data improve significantly.

The USLS has a significant reduction effect on all five barriers that affect team collaboration, the largest reduction is in the lack of commitment (the third obstacle), followed by avoidance of responsibility (the fourth obstacle). This is because the ubiquitous smart learning space can enhance collaborative learning ability by supporting the smooth implementation of collaborative learning activities, during the process, commitment (the third obstacle), avoidance of responsibility (the fourth obstacle) had been avoided.

CHAPTER 5

CONCLUSION, DISSCUSION, RECOMMENDATION

5.1 Summary of The Study

5.1.1 The objectives of the study

By innovating learning concept and educational technology method to enhance the learning space and improve the learning validity under the background of smart education and the COVID-19 pandemic. The objectives include:

1) to study the stakeholder' interests in the ubiquitous smart learning space to enhance collaborative ability and critical thinking.

2) to construct the ubiquitous smart learning space.

3) to study user's satisfaction on its ubiquitous smart environment.

4) to study collaborative ability and critical thinking of students learning with ubiquitous smart learning space.

5.1.2 The research questions

The main questions of this study are:

1) Is it necessary to construct the ubiquitous smart learning space and who are the stakeholders and what are their core interests to enhance collaboration and critical thinking ability?

2) What elements should be included in a ubiquitous smart learning space?

3) What are users' level satisfaction on ubiquitous smart learning space?

4) Can the ubiquitous smart learning space improve the leaners' collaboration and critical thinking ability?

5.1.3 The research procedures

Since the reconstruction of learning space is a very complex project, to effectively solve the principles of learning space reconstruction construction, functional positioning, user population, architecture design, implementation strategy, key technology selection and to ensure the learning effect, the author according to the method of software engineering, the research positioned three core problems, divided into 4 research stages of study.

5.2 Summary of The Findings

The tasks and results addressed in each phase are:

(1) Phrase 1 (chapter 2) complete 4 main tasks.

1) Did the literature analysis on education change trends, by analyzing trends in technology, social and education change, changes in learning characteristics of different times, and trends in learning patterns then found that smart education, smart learning, and ubiquitous learning were new education trend. The research studied two main backgrounds and the important challenges that future education is being faced. Background 1 pointed out that the learning space need to provide a smart learning environment supporting lifelong learning. In background 2, by studying the drawbacks exposed by traditional online education under the epidemic, it was found that traditional online education could not meet the requirements of learners and teachers. This shows that it is necessary to reconstruct the learning space.

2) Compared learning space evolution framework and implemented projects and found out ubiquitous collaborative intelligent learning environment with 4A3E learning

style, can meet PSST framework.

3) Found out technology adoption principle by researching evolution models in online education should (1) perceived usefulness and perceived ease of use (2) the introduction of usual tests and evaluation of learning results into learning probably increase the willingness of learners to use learning space for learning (3) perceived fun (4) perceptual knowledge is available by embedding suitable learning and teaching models.

4) And found that collaboration learning can enhance 7 skills,

(1) Boosts problem-solving skills

(2) Improving decision making skills

(3) Develops productivity and efficiency

(4) Increases critical thinking

(5) Builds trust

(6) Development of communication skills

(7) Improves social interactions

(2) Phrase 2 (chapter4): researched the stakeholders' main interest and function needs by surveying 477 students of 28 majors , and interviewing 5 managers and 10 teachers. The result showed the all the functions that included seven categories: interactive function, collaborative function, teaching function, inquiry function, creative function, private function, and social function, were necessary to stakeholders.

(3) Phrase 3 (chapter 4), based on multi-stakeholder needs analysis and technology adoption principles, we identified the program's functional positioning, key technologies, and implementation strategies. The research proposed USLS architecture model which was built on top of ubiquitous network and cloud computing with the two main features, smart and ubiquitous, to meet the functional positioning of experience-oriented, flexible, and convenient, reliable, and secure, open, and compatible, and updated and iterative. There are 4 types of users include teacher, student, service providers and administer. They organized USLS learning community. Based on functions and users' relationship, we proposed 7 layers construction architecture model and elements. There are five specific implementations core technologies in USLS deployments as follows: Cloud computing, collaboration and interaction platform, Multi-experience Development Platforms, technology middle platform (Zhongtai) with intelligence engine. At last, we implemented the framework, and give the symbiosis space components and a learning place, consisting of a total of seven subspaces, such as interactive space, collaborative space, transmission space, creative space, inquiry space, social space, and private space, then give cases of each subspace (Appendix 10).

(4) Phrase 4 (chapter 5): mainly introduces the five-learning models supported by the ubiquitous smart learning space. To guarantee development, we immediately conducted a satisfaction survey on the collaborative learning environment and efficiency, with 275 students and 10 teachers, the results show that the collaborative learning environment of the ubiquitous learning space effectively supports collaborative learning activities and effects.

(5) Phrase 4 (chapter 4) In order to further prove the role of space design, development and technical strategy in promoting learning ability and thinking cognitive ability, we conducted collaborative learning ability and critical thinking experiment on 64 students in the 2021 class of computer science (1), and after 20 weeks of experiments, the final data results showed that the ubiquitous smart learning space has an extremely significant effect on the improvement of collaborative learning and critical thinking.

5.3 Discussion

5.3.1 Research question 1) Is it necessary to construct the ubiquitous smart learning space and who are the stakeholders and what are their core interests to enhance collaboration and critical thinking ability?

(1) Although critical thinking ability is very emphasized in the education and teaching goals, due to the overemphasis on knowledge learning in traditional teaching, in practice, educators still pay less attention to the development of critical thinking ability. This may stem from the challenges of traditional critical thinking paradigms and strategy implementation.

1) Heavy reliance on teachers themselves should be critical thinkers. To solve the problem of improving students' critical thinking, we must first solve teachers' critical thinking. Teachers' critical thinking also depends on their teachers, then cultivating students' critical thinking will fall into an infinite loop. If there are not enough people in a country and region to notice or can undertake the mission of promoting critical thinking ability, the cultivation of students' critical thinking will not be realized. Therefore, relying on the thinking of teachers themselves with traditional paradigms and strategy implementation cannot meet the current talent training goals effectively and quickly.

2) Centered on teaching, the effect mainly depends on the design of teaching activities in formal classroom. The strategy basically uses a single learning scaffold to design a certain learning activity or teaching. Students carry out a certain activity in the arranged scene but not in anywhere they are learning. The enhancement of critical thinking by a single learning scaffold or instructional design cannot be adapted for lifelong learning, u-learning, and student-centered educational trends.

3) Heavy reliance on traditional school education, resulting in unsustainable. The effective implementation of the strategy needs to be carried out in the traditional teaching mode: teachers, students, and formal schooling. In this paradigm, there is no chances for students who leave or a graduate from formal education to use the strategies. In fact, after leaving school, people are more likely to improve their critical thinking to survival. People with different educational backgrounds, life experiences, social status, and social roles are eager to learn autonomously, ubiquitously, and easily. So, learner-centered, or open-loop learning is the mainstream trend, but the above-mentioned critical thinking paradigms are too reliance on teachers and school environment to be sustainable.

4) Stakeholders are relatively less. The above paradigm relies on teachers themselves, on traditional educational environment, and mainly on teaching design, which leads to most of the training objects being traditional students. It cannot provide effective support to other stakeholders. To avoid the limitations caused by this, the author proposed a critical thinking training paradigm based on constructing ubiquitous smart learning spaces. The paradigm is based on the principles of transforming or enhancing traditional learning environments using technology to support interactive, collaborative learning, problem-based learning activities, to promote collaboration and critical thinking ability. Ubiquitous smart learning space supports effective teaching strategies in the learning process and builds a learner-centered by integrating multi-stakeholders and its evolutes by adopting advanced architectural strategies, and it can naturally and continuously improve critical thinking ability.

5.3.2 Research question 2) What elements should be included in a ubiquitous smart learning space?

Core stakeholders and core interests. Existing research provides a variety of effective strategies and activities to promote the development of students' critical

thinking and collaboration ability, and there is a lot of overlap between the various strategies for teaching critical thinking. Teachers need to understand that the teaching of ability should be integrated into the implementation of all courses; research shows that questioning, classroom discussion, reading, writing, cooperative learning and problem-based are the most effective activity or method to promote collaboration and critical thinking ability; new technologies with information technology as the core have a huge role in the implementation of teaching, but if they cannot be combined with those activates in teaching and learning, there is no obvious effect on students abilities development. This requires the designer to do the need analysis and function design based on core stakeholders and core interests very carefully, otherwise technologies and functions cannot match teaching and learning activities, such questioning, classroom discussion, reading, writing, cooperative learning, through all courses.

5.3.3 Research question 3) What are users' level satisfaction on ubiquitous smart learning space?

Learning environments satisfaction. Evolving educational technology requires teachers to use new technology to create a good learning environment and achieve established learning goals. Modern technologies and related networks such as blogs, wikis, YouTube, Twitter and Facebook and other web 2.0 tools or social networking sites have developed rapidly in the first decade of the 21st century. Studies by many scholars have shown that the use of social networking sites to achieve educational goals is a popular educational policy in many countries. Research by P. Duffy shows that engaging in learning through blogging helps students develop higher-order thinking skills such as critical thinking, analytical thinking, creative thinking, intuitive thinking, associative thinking, and analogical thinking. The researchers further noted that to promote the development of these skills, the following points need to be kept in mind in educational teaching activities: (1) Make comments based on learning topics and students' responses; (2) Provide space for students to collaborate on course material; (3) Provide space for online comments or peer comments. S. Minocha claimed that social networking sites did not provide many new ways for students to improve their critical thinking. All the discussion and communication platforms provided by social networking sites can promote students' critical thinking, because discussion itself can promote the development of students' critical thinking ability.

Based on above suggestion, to guarantee the collaborative ability of learning environment is the key factor for improve user's satisfaction and higher-order thinking skills, so technology adoption strategy on collaborative learning environment should be choose carefully.

To try to support more discussion and collaborative ability in different situations, in this research, with collaborative learning environment, I designed five ubiquitous smart learning models, namely, independent learning model, collaborative learning model, situated learning model, creative learning model and critical thinking learning model, and analyze the satisfaction of collaborative learning environment and carry out experiments on critical thinking and collaborative learning skill.

5.3.4 Research question 4) Can the ubiquitous smart learning space improve the leaners' collaboration and critical thinking ability?

The results showed that users satisfied with collaborative learning environment of ubiquitous smart learning space and conveyed that it can support the development of collaborative learning activities thus enhance collaborative learning, meanwhile, the experiment proved that USLS had a positive effect on the development of students' critical thinking and collaborate learning. so, technology adoption is very important for improve user's satisfaction and higher-order thinking skills, when design ubiquitous learning platform model, designer need focus on user's core interests then chose

adoption technology. There are researchers have noticed its necessary. Vivien Lin, Yu-Hsuan Lin, Min-Chai Hsieh, Gi-Zen Liu, CA, Hao-Chiang Koong (2021) designed a multimodal ubiquitous learning application (MULA) with different augmenting effects for enhancing English as a Foreign Language (EFL) academic writing instruction. In a pilot project, their survey responses and interview feedback about (a) the ubiquitous learning model, (b) effective writing facilitation, (c) motivation, self-efficacy, and attitude, (d) self-regulation, and (e) system usability and introduced seven affordances that made MULA a potential tool and pointed that the seven affordances were effective design elements for multimodal context-aware ubiquitous learning.

Arajo, Rafael, D., Dora, Fabiano, A., Brant-Ribeiro, Taffarel, Cattelan, Renan, G., Ferreira, Hiran, N. M. (2020) proposed an approach for creating and personalizing LOs through a probabilistic proposal of the Felder and Silverman Learning Styles Model. And they integrated into a ubiquitous educational platform and experimented in real settings. Results indicate the existence of correlations between different types of interactions carried out by students and their respective LSs. Their research pointed that it was necessary to consider people behave and learn in a different pace in the teaching/learning process.

The main reason for ubiquitous smart learning space can improve the leaners' collaboration and critical thinking ability is that we considered people behave and learn in a different pace in the teaching/learning process, did core stakeholder and their core interests very carefully, then technology implementation strategies had been chosen properly to meet users expected experiences when use it.

5.4 Conclusion

The result proved that ubiquitous smart learning space have very high satisfaction and can improve the leaners' collaboration and critical thinking ability. This is mainly following works:

(1) used software engineering requirements, development, design, and implementation strategies to realize the conceptual model of PSST learning space and realize the integration of education, technology, society, and methodology. By studying education and learning evolution, core stakeholders and core interests, the research found out learning community and their activity and relationship model, which makes the types and roles of the stakeholders in using clearer and assured that all the functions were necessary for stakeholder's core interest.

(2) futures and elements of learning space environment model and architecture model are given in specific, this makes the construction principle very clearly, and can offer 5 different learning models to meet people behave and learn in a different pace in the teaching/learning process.

(3) new technology solutions has been found. According to the principle of TAM technology adoption theory and objectives, we used Zhongtai strategy, low-code development technology to develope the integration and application of complex technologies, which can continuously be optimized and iterated at low cost, providing a new method for relizing virtual learning.

5.5 Recommendations

5.5.1 Recommendations for Implementing

(1)When building a virtual learning environment or online education platform, always pay attention to the positive correlation between the learning environment, learning activities and learning effects.

The results of the collaborative learning environment satisfaction survey show that there is a positive correlation between the collaborative learning environment, collaborative learning activities and collaborative learning effects. The refection from this result is that an effective learning environment must support effective participation in activities. Only with this understanding, the designed virtual learning platform is likely to be recognized, selected, and continuously used by learners. Ignoring the relationship between the three is likely to result in a high dropout rate, failing to achieve the stakeholders' expected goals of education, technology, society, and methodology, and ultimately being abandoned even affects the confidence of using virtual learning.

(2) Functional design recommendations.

The data concludes that the functional design of the ubiquitous smart learning space can be applied to learning at any time, any place and anyway on different devices of different genders, different ages, different majors, and users over 20 years old are main group. However, it should be noted that 1) meeting the use of fragmented time learning on mobile phones have priority, because the usage rate of smartphones is 100%, and the mobile interface should be satisfied first when designing and choosing technology. 2) Different from the previous interaction methods, the static text transmission requirements of e-mail are significantly reduced, and learners need more direct, dynamic video and voice to carry out collaborative learning in a way that always has a sense of social integration. 3) Compared with female, male have a stronger creative interest, which requires functional design not only to organize and manage learners according to classes and courses, but also to allow learners to organize and manage teams according to their interests.

5.5.2 Recommendations for Future Study

(1) Critical thinking ability can be continually trained by using ubiquitous smart learning space.

The main reason is that technology enhance people to collaborate with each other. Collaboration is an important approach and inspiring for training people's critical thinking through technology.

Through tools in USLS, such as mind mapping, project management, online documents, and online meetings, learners can divide labor, cooperate, and compete on project progress, can help team members focus on the problem itself, reducing distrust caused by human conflicts, and members investing in accordance with the division of labor, and the results are automatically fed back to each member, avoid the risk of members ignoring the results, thereby improving the collaborative learning ability of team members unconsciously. The cultivation of collaborative ability can be realized unconsciously by regulating the learning activities process with technology enhancement. And it can improve critical thinking continually.

(2) Satisfaction maintain strategies.

To maintain user wiliness to use USLS, in future, we will continue research on 1) further optimize, integrate, and expand USLS, and conduct pilot projects in places. 2) optimize, integrate reality technology to enhance more majors' immersive learning. 3) test users' use efficiency on other learning model to optimize its function and framework.

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APPENDIX

Page

Appendix A

Questionnaire on Key Functions of Ubiquitous Smart Learning Space

Thank you for participating in the survey for this study, which aims to understand the key elements of learning stakeholders' use of ubiquitous smart learning spaces, which will help us provide better support services for your learning.

You will complete this questionnaire anonymously. All information you provide in this questionnaire will be used for this research only.

Part 1: Your Background Information

1. Age:

2. Gender: ☐ male ☐ female

3. Your role: ☐ Learner

4. Major:

Part 2: Your Study Status

1. Please tick the following digital devices you own:

☐ Desktop computer ☐ Laptop computer ☐ Tablet computer (such as iPad)

☐ Smart phone (mobile phone with Internet access function)

Other digital equipment (please list):

2. Among the learning platforms listed below, please tick according to your use in learning:

Table A.1 Learning platform

Learning platform or app	used
MOOC (such as Coursera, Udacity, edX, MOOC China, XuetangX, Chinese University MOOC platform, etc.)	☐
Micro-courses (such as the official website of the National University Micro-Course Teaching Competition, Phoenix Micro-course, Micro-course Network, etc.)	☐
Short video apps (such as Douyin, Kuaishou, etc.)	☐
Knowledge service APP (such as Himalaya, Get, Learning Power, etc.)	☐
Social network (such as WeChat, QQ, Bilibili, etc.)	☐
Wiki (such as Baidu Baike, Wikipedia, etc.)	☐
Weibo (such as QQ Weibo, Sina Weibo, etc.)	☐
Google Classroom	☐
Other applications (please list)	

Part 3: Your Recognition of The Key Functions of The Ubiquitous Smart Learning Space

The ubiquitous smart learning space is a new learning space that can be used anytime and anywhere with the help of the smart platform. Learning stakeholders can use the learning space to learn, share and exchange information and knowledge. The purpose of this questionnaire is to understand the key functions that learning stakeholders expect the ubiquitous smart learning space to have, and the findings will help us provide better support services for learning stakeholders.

Please read each sentence carefully and choose the corresponding answer according to your agreement with each sentence. If you have a better suggestion, please select "Other" and give your score and desired features:

Table A.2 Key Functions and core interest

Space name	Key function	Very unnecessary	Unnecessary	General	Necessary	Very necessary
1. Interactive function	Instant messaging	1☐	2☐	3☐	4☐	5☐
	The message must be reached	1☐	2☐	3☐	4☐	5☐
	Voice conference	1☐	2☐	3☐	4☐	5☐
	Video conference	1☐	2☐	3☐	4☐	5☐
	Online translation	1☐	2☐	3☐	4☐	5☐
	Other functions	1☐	2☐	3☐	4☐	5☐
	Other functional description					
2. Collaborative features	Online documentation	1☐	2☐	3☐	4☐	5☐
	Shared storage	1☐	2☐	3☐	4☐	5☐
	Learning circle	1☐	2☐	3☐	4☐	5☐
	E-mail	1☐	2☐	3☐	4☐	5☐
	Project management	1☐	2☐	3☐	4☐	5☐
	Other functions	1☐	2☐	3☐	4☐	5☐
	Other functional description					
3. Teaching function	Smart classroom	1☐	2☐	3☐	4☐	5☐
	MOOC learning	1☐	2☐	3☐	4☐	5☐
	Micro-learning	1☐	2☐	3☐	4☐	5☐
	Short video	1☐	2☐	3☐	4☐	5☐
	Live online	1☐	2☐	3☐	4☐	5☐
	Online class	1☐	2☐	3☐	4☐	5☐
	Other functions	1☐	2☐	3☐	4☐	5☐
	Other functional description					
4. Exploratory function	Mind Mapping	1☐	2☐	3☐	4☐	5☐
	Digital laboratory	1☐	2☐	3☐	4☐	5☐
	Digital library	1☐	2☐	3☐	4☐	5☐
	Smart search	1☐	2☐	3☐	4☐	5☐
	Smart writing	1☐	2☐	3☐	4☐	5☐
	Other functions	1☐	2☐	3☐	4☐	5☐
	Other functional description					
5. Creative features	AR design	1☐	2☐	3☐	4☐	5☐
	VR Design	1☐	2☐	3☐	4☐	5☐
	3D experience	1☐	2☐	3☐	4☐	5☐
	Application Design	1☐	2☐	3☐	4☐	5☐

Table A.2 (Continued)

Space name	Key function	Very unnecessary	Unnecessary	General	Necessary	Very necessary
	Data analysis	1☐	2☐	3☐	4☐	5☐
5. Creative features	Other functions	1☐	2☐	3☐	4☐	5☐
	Other functional description					
	Personal circle	1☐	2☐	3☐	4☐	5☐
	Personal storage	1☐	2☐	3☐	4☐	5☐
	Encrypted transmission	1☐	2☐	3☐	4☐	5☐
6. Private space	Secret chat	1☐	2☐	3☐	4☐	5☐
	Share privately	1☐	2☐	3☐	4☐	5☐
	Other functions	1☐	2☐	3☐	4☐	5☐
	Other functional description					
	Circle of friends	1☐	2☐	3☐	4☐	5☐
	Social network	1☐	2☐	3☐	4☐	5☐
	Knowledge service	1☐	2☐	3☐	4☐	5☐
7. Social space	Social practice	1☐	2☐	3☐	4☐	5☐
	Subject competition	1☐	2☐	3☐	4☐	5☐
	Other functions	1☐	2☐	3☐	4☐	5☐
	Other functional description					

Appendix B

Interview Outline for Reconstruction of Ubiquitous Smart Learning Space

Date : **Location：**
Interviewee: **Interviewer:**

Part one: basic Information
1. Name
2. Occupation
3. Position
4. Length of time engaged in related work
5. Have you ever used a similar online learning platform? If yes, please give an example
6. Will you continue to use it? Any reason?
7. What equipment do you often use?
Part Two: business
1. What business do you hope that the ubiquitous smart learning space should include at least?
2. Which of the above business are implemented?
3. Do the above businesses need to be linked with other businesses? If yes, please enumerate.
4. Does the new business demand or business demand change quickly? What is the approximate frequency?
5. How long is the longest period you can endure to develop?
6. How do you usually collaborate with other business leaders?
Part Three: functional requirements
1. What functions do you need to support learner?
2. What are your basic requirements for functional design? For example: function update speed, function usage habits, function working equipment and operating environment, etc.
3. Which functions can increase your interest in using?
4. Which functions make you feel that the learning space has a "smart" experience?
5. What features can improve learning efficiency and work efficiency?
6. What features are missing that you will give up?
7. Do you have a commonly used and recommended functional design platform?
8. "What function can embody the characteristics of "ubiquitous"?
Part Fourth: keep learning the strategy

1. What causes learner to give up using the space?
2. What strategies would you use to stimulate your willingness to support other in this space?
3. What makes you will to recommend the "Ubiquitous Smart Learning Space" to others?
Part Five: strategies for improving learning skills
1. What learning skills do you think the learning space should improve?
2. What functions can be used to improve collaboration and critical thinking ability?
3. Compared with the traditional school learning space, what is its effect on learning?
4. Some people say that traditional learning spaces are more conducive to people's interaction and communication than smart learning spaces. Do you agree?

Appendix C

Collaborative Learning Model Satisfaction Questionnaire

Thank you for participating in this study, which is designed to investigate the satisfaction of learning stakeholders with the Ubiquitous Smart Learning Space collaborative learning model and will help us to provide better support services for your learning.

You will be asked to complete this questionnaire anonymously. All information you provide in this questionnaire will be used only for the purpose of this study.

Part I Your background information

Please answer the following questions related to your basic information:

1. Age: 2. Gender: ☐ Male ☐ Female

3. Your role: ☐ student ☐ teacher ☐ administrator ☐ service provider

4. Professional:

Please check the following digital devices that you own.

☐Desktop computer ☐Laptop computer ☐Smart phones

☐Tablet (e.g., iPad)

Other digital devices (please list them).

Part II Your satisfaction with the collaborative learning model of Ubiquitous Smart Learning Space

Using the Ubiquitous Smart Learning Space (USLS) platform as an example, please answer the questions by objectively evaluating your own level of agreement with the following statements, checking the boxes that match your level of agreement for each question.

Table C.1 Satisfaction With The Collaborative Learning Environment

Satisfaction Classification	Key Indicators	Very dissatisfied	Dissatisfaction	Normal	Satisfied	Very satisfied
1.Collaborative Learning Environment	Digital Equipment	1☐	2☐	3☐	4☐	5☐
	Interaction Capability	1☐	2☐	3☐	4☐	5☐
	Collaboration Capability	1☐	2☐	3☐	4☐	5☐
	Learning Resources	1☐	2☐	3☐	4☐	5☐
	Learning Applications	1☐	2☐	3☐	4☐	5☐
	Intelligent Perception	1☐	2☐	3☐	4☐	5☐
	Comprehensive Review	1☐	2☐	3☐	4☐	5☐
2.Collaborative learning activities	Flexible Grouping	1☐	2☐	3☐	4☐	5☐
	Unified Goals	1☐	2☐	3☐	4☐	5☐
	Clarify tasks	1☐	2☐	3☐	4☐	5☐
	Make Plan	1☐	2☐	3☐	4☐	5☐
	Intelligent division of learning	1☐	2☐	3☐	4☐	5☐
	Collaboration	1☐	2☐	3☐	4☐	5☐
	Share the results	1☐	2☐	3☐	4☐	5☐
	Collective evaluation					

Table C.1 (Continued)

Satisfaction Classification	Key Indicators	Very dissatisfied	Dissatisfaction	Normal	Satisfied	Very satisfied
	Learning Resources	1☐	2☐	3☐	4☐	5☐
	Learning Motivation	1☐	2☐	3☐	4☐	5☐
3.Collaborative Learning Effectiveness	Learning Engagement	1☐	2☐	3☐	4☐	5☐
	Interest in Learning	1☐	2☐	3☐	4☐	5☐
	level of enjoyment	1☐	2☐	3☐	4☐	5☐
	Level of effort	1☐	2☑	3☐	4☐	5☐

Appendix D

Collaborative Learning Model Interview Outline

Thank you for participating in the interviews for this study, which aims to investigate the extent to which learning stakeholders agree to use the Ubiquitous Smart Learning Space collaborative learning model, which will help us to provide better support services for learners' learning. All the information you provide in this questionnaire will be used for the purpose of this study only.

Part I: Your background information

Please answer the following questions related to your basic information:

1. Age:
2. Gender: ☐Male ☐Female
3. Your Role: ☐Learner ☐Teacher ☐Administrator ☐Service Provider
4. Professional:

Part II: How much do you agree with the collaborative learning model of Ubiquitous Smart Learning Space

Using the Ubiquitous Smart Learning Space (USLS) platform's support and use of collaborative learning as an example, please indicate your own level of agreement with the following questions through an objective evaluation.

1. How is the teaching effect?
2. Can the teaching model meet the requirements? What are the characteristics compared with the traditional model?
3. Are the teaching methods rich? How easy, engaging, and effective is the support for learners?
4. Please evaluate the intelligent support of USLS, such as intelligent analysis and intelligent recommendations, etc.

Appendix E

Chinese Version of Critical Thinking Inventory

Name: _____ Age: _____

Education: undergraduate master Gender: male female

Each of the following questions has a six-level grid, identifying the box you choose with "√":

Table D.1 Critical Thinking Ability

Questions	agree ◄——► disagree					
1. Considering all the possibilities of events when faced with difficulties which is impossible for me	☐	☐	☐	☐	☐	☐
2. Researching new things can enrich my life richer	☐	☐	☐	☐	☐	☐
3.The best argument often comes from the momentary feeling when facing a certain problem	☐	☐	☐	☐	☐	☐
4. My attention is very susceptible to the external environment	☐	☐	☐	☐	☐	☐
5.Faced with a controversial topic, it is extremely difficult to choose one of different opinions	☐	☐	☐	☐	☐	☐
6. I will feel anxious when others only use shallow arguments to support good ideas	☐	☐	☐	☐	☐	☐
7. The truth is one's own opinion	☐	☐	☐	☐	☐	☐
8. I always analyze the question before I answer it	☐	☐	☐	☐	☐	☐
9. I appreciate my precise thinking ability	☐	☐	☐	☐	☐	☐
10.If it has four reasons to agree with something, and only one objection, I will choose to agree with it	☐	☐	☐	☐	☐	☐
11. Pay a high price (for example, money, time, energy), and you will surely get better opinions	☐	☐	☐	☐	☐	☐
12.Most of the courses at school are boring and not worth taking	☐	☐	☐	☐	☐	☐
13. Quizzes that require thinking rather than answering entirely from memory are more suitable for me	☐	☐	☐	☐	☐	☐
14. I can keep talking about a problem, but I don't care if the problem is solved	☐	☐	☐	☐	☐	☐
15.My curiosity and thirst for knowledge are appreciated by others	☐	☐	☐	☐	☐	☐
16. Even if there is evidence that does not match my ideas, I will stick to my ideas	☐	☐	☐	☐	☐	☐
17.In a group discussion, if someone's opinion is deemed wrong by others, he has no right to express his opinion	☐	☐	☐	☐	☐	☐
18. I am not a very logical person, but I often pretend to be logical	☐	☐	☐	☐	☐	☐
19. I can easily organize my own thinking	☐	☐	☐	☐	☐	☐
20. Before I face an important choice, I will try to collect all the relevant information	☐	☐	☐	☐	☐	☐
21. When facing a problem, because I can make an objective analysis, my peers will come to me to decide	☐	☐	☐	☐	☐	☐
22. I have an open mind; I don't know what is true and what is false	☐	☐	☐	☐	☐	☐
23. When I see that the manual of a new product is complicated and difficult to understand, I will give up reading on	☐	☐	☐	☐	☐	☐
24. It is important for me to understand what others think about things	☐	☐	☐	☐	☐	☐
25.My beliefs must be supported by evidence	☐	☐	☐	☐	☐	☐
26.If possible, I will try to avoid reading	☐	☐	☐	☐	☐	☐
27. People say I am too impulsive in making decisions	☐	☐	☐	☐	☐	☐

Table D.1 (Continued)

Questions	agree ◄——► disagree					
28.Compulsory subjects in schools are a waste of time	☐	☐	☐	☐	☐	☐
29. When dealing with complex issues, I feel panicked	☐	☐	☐	☐	☐	☐
30. Foreigners should learn our culture instead of us to understand their culture	☐	☐	☐	☐	☐	☐
31. People think I am hesitant when deciding	☐	☐	☐	☐	☐	☐
32. To oppose the opinions of others, you must give reasons	☐	☐	☐	☐	☐	☐
33.When I express my opinion, it is impossible to remain objective	☐	☐	☐	☐	☐	☐
34. I am satisfied that I can come up with creative choices	☐	☐	☐	☐	☐	☐
35. I'm trying to make less subjective judgments	☐	☐	☐	☐	☐	☐
36. I find that I often evaluate the arguments of others	☐	☐	☐	☐	☐	☐
37.I firmly believe in what believes in myself	☐	☐	☐	☐	☐	☐
38.It is not so important to actively try to solve all kinds of problems	☐	☐	☐	☐	☐	☐
39. Others shouldn't force me to defend my opinion	☐	☐	☐	☐	☐	☐
40.When deciding, others expect me to formulate appropriate guidelines for guidance	☐	☐	☐	☐	☐	☐
41. I look forward to facing challenging things	☐	☐	☐	☐	☐	☐
42.It is meaningful to study the ideas of foreigners	☐	☐	☐	☐	☐	☐
43. I have a strong thirst for knowledge	☐	☐	☐	☐	☐	☐
44. I will only look for some facts that support my opinion, but will not look for some facts that oppose my opinion	☐	☐	☐	☐	☐	☐
45. Solving difficulties is fun	☐	☐	☐	☐	☐	☐
46. I am satisfied that I can understand the views of others	☐	☐	☐	☐	☐	☐
47.Use "anaphors" to understand the problem, like driving a boat on a highway	☐	☐	☐	☐	☐	☐
48. I can be considered a logical person	☐	☐	☐	☐	☐	☐
49. I like to find out how things work	☐	☐	☐	☐	☐	☐
50. When the problem becomes tricky, others will expect me to continue to deal with it	☐	☐	☐	☐	☐	☐
51.When dealing with a problem, we must first figure out the crux of the problem	☐	☐	☐	☐	☐	☐
52. Most of my opinions on controversial topics follow the person I last discussed	☐	☐	☐	☐	☐	☐
53. No matter what the topic, I am eager to know more relevant content	☐	☐	☐	☐	☐	☐
54.Is impossible to know which one is the better solution	☐	☐	☐	☐	☐	☐
55.The best way to solve a problem is to ask others for the answer	☐	☐	☐	☐	☐	☐
56. There are many problems I will be afraid to find the truth	☐	☐	☐	☐	☐	☐
57. I am good at dealing with problems methodically	☐	☐	☐	☐	☐	☐
58. It is not that important to be open to different worldviews (e.g., evolution, theism)	☐	☐	☐	☐	☐	☐
59. I will try to learn everything, even if I don't know when they are useful	☐	☐	☐	☐	☐	☐
60.Life experience tells me that I don't have to be too logical in doing things.	☐	☐	☐	☐	☐	☐

Table D.1 (Continued)

Questions	agree ◄——► disagree					
61.The essence of the thing is consistent with its appearance	☐	☐	☐	☐	☐	☐
62. Since I know how to make this decision, I won't think about other options again and again	☐	☐	☐	☐	☐	☐
63.A decision made by a powerful person is the right decision	☐	☐	☐	☐	☐	☐
64. We don't know what standard should be used to measure most problems	☐	☐	☐	☐	☐	☐
65. Everyone has the right to express their opinions, but I will ignore them	☐	☐	☐	☐	☐	☐
66. I am good at planning a systematic plan to solve complex problems	☐	☐	☐	☐	☐	☐
67.Personal experience is the only criterion for verifying the truth	☐	☐	☐	☐	☐	☐
68. I am afraid of asking questions in class	☐	☐	☐	☐	☐	☐
69. I often think about right and wrong in practice and experience	☐	☐	☐	☐	☐	☐
70. I don't doubt that everyone takes it for granted	☐	☐	☐	☐	☐	☐

Appendix F

Team Collaboration Obstacle Evaluation Form

Number	Content	Score			Total
		Frequent（3）	Occasionally（2）	Infrequently（1）	
1	When team members' words and deeds are improper or detrimental to the group, they will immediately and sincerely admit their mistakes				
2	Team members dare to publicly admit their shortcomings and mistakes				
3	Team members understand each other's business life and can talk about it with each other				
4	The team members are very enthusiastic when discussing things, and there is no situation where they are wary of each other				
5	The team's memories are encouraging but not boring				
6	During the meeting, everyone brought out the most important and most difficult issues to discuss together				
7	Team members understand the work they are responsible for at the same time, and know the effect of the work on the team benefit				
8	Although there were differences at the beginning, at the end of the meeting, everyone believed that they could act according to the consensus reached.				
9	Team members can find a clear solution after discussing the problem and start implementing it immediately				
10	Team members remind each other of their shortcomings or behaviors that are not conducive to work				
11	If someone is fired, the team members are very concerned about it				
12	Team members monitor each other's work plans and progress				
13	Team members are willing to sacrifice the interests of the department or individuals for the benefit of the collective				
14	If the collective goal is not achieved, morale will be greatly affected				
15	Team members are not eager to get affirmation of others' contributions to themselves, but can quickly point out the achievements of others				

Appendix G

IOC for Pre- Key function and stakeholders

(Item-Objective Congruence Index: IOC)

Serial number	Expert opinion					IOC	Interpretation
	1	2	3	4	5		
Part 1							
1	+1	+1	+1	+1	+1	5/5 = 1	Pass
2	+1	+1	+1	+1	+1	5/5 = 1	pass
3	+1	+1	+1	+1	+1	5/5 = 1	Pass
4	+1	+1	+1	+1	+1	5/5 = 1	Pass
5	+1	+1	+1	+1	+1	5/5 = 1	Pass
6	+1	+1	+1	+1	+1	5/5 = 1	Pass
Part 2							
1	+1	+1	+1	+1	+1	5/5 = 1	Pass
2	+1	+1	+1	+1	+1	5/5 = 1	Pass
3	+1	+1	+1	+1	+1	5/5 = 1	Pass
4	+1	+1	+1	+1	+1	5/5 = 1	Pass
5	+1	+1	+1	+1	+1	5/5 = 1	Pass
6	+1	+1	+1	0	+1	4/5=0.8	Pass
Part 3							
1	+1	+1	+1	+1	+1	5/5 = 1	Pass
2	+1	+1	+1	+1	+1	5/5 = 1	Pass
3	+1	+1	+1	+1	+1	5/5 = 1	Pass
4	+1	+1	+1	+1	+1	5/5 = 1	Pass
5	+1	+1	+1	+1	+1	5/5 = 1	Pass
6	+1	+1	+1	+1	+1	5/5 = 1	Pass
Part 4							
1	0	0	0	0	+1	1/5= 0.2	Not Pass
2	-1	-1	+1	+1	0	0/5=0	Not Pass
3	+1	+1	0	0	-1	1/5= 0.2	Not Pass
4	+1	0	0	0	+1	2/5= 0.4	Not Pass
5	0	+1	+1	+1	-1	2/5=0.4	Not Pass

Appendix H

IOC for Renewed- Key Function and Stakeholders

(Item-Objective Congruence Index: IOC) R

Serial number	Expert opinion					IOC	Interpretation
	1	2	3	4	5		
Part 1							
1	+1	+1	+1	+1	+1	5/5 = 1	Pass
2	+1	+1	+1	+1	+1	5/5 = 1	pass
3	+1	+1	+1	+1	+1	5/5 = 1	Pass
4	+1	+1	+1	+1	+1	5/5 = 1	Pass
Part 2							
1	+1	+1	+1	+1	+1	5/5 = 1	Pass
2	+1	+1	+1	+1	+1	5/5 = 1	Pass
Part 3							
1	+1	+1	+1	+1	+1	5/5 = 1	Pass
2	+1	+1	+1	+1	+1	5/5 = 1	Pass
3	+1	+1	+1	+1	+1	5/5 = 1	Pass
4	+1	+1	+1	+1	+1	5/5 = 1	Pass
5	+1	+1	+1	+1	+1	5/5 = 1	Pass
6	+1	+1	+1	+1	+1	5/5 = 1	Pass
7	+1	+1	+1	+1	+1	5/5 = 1	Pass

Appendix I

IOC on Interview Outline for Reconstruction of Ubiquitous Smart Learning Space

(Item-Objective Congruence Index: IOC) R

Serial number	Expert opinion					IOC	Interpretation
	1	2	3	4	5		
Part 1							
1	+1	+1	+1	+1	+1	5/5 = 1	Pass
2	+1	+1	+1	+1	+1	5/5 = 1	pass
3	+1	+1	+1	+1	+1	5/5 = 1	Pass
4	+1	+1	+1	+1	+1	5/5 = 1	Pass
5	+1	+1	+1	+1	+1	5/5 = 1	Pass
6	+1	+1	+1	+1	+1	5/5 = 1	Pass
7	+1	+1	+1	+1	+1	5/5 = 1	Pass
Part 2							
1	+1	+1	+1	+1	+1	5/5 = 1	Pass
2	+1	+1	+1	+1	+1	5/5 = 1	Pass
3	+1	+1	+1	+1	+1	5/5 = 1	Pass
5	+1	+1	+1	+1	+1	5/5 = 1	Pass
6	+1	+1	+1	+1	+1	5/5 = 1	Pass
Part 3							
1	+1	+1	+1	+1	+1	5/5 = 1	Pass
2	+1	+1	+1	+1	+1	5/5 = 1	Pass
3	+1	+1	+1	+1	+1	5/5 = 1	Pass
4	+1	+1	+1	+1	+1	5/5 = 1	Pass
5	+1	+1	+1	+1	+1	5/5 = 1	Pass
6	+1	+1	+1	+1	+1	5/5 = 1	Pass
7	+1	+1	+1	+1	+1	5/5 = 1	Pass
8	+1	+1	+1	+1	+1	5/5 = 1	Pass
Part 4							
1	+1	+1	+1	+1	+1	5/5 = 1	Pass
2	+1	+1	+1	+1	+1	5/5 = 1	Pass
3	+1	+1	+1	+1	+1	5/5 = 1	Pass
Part 5							
1	+1	+1	+1	+1	+1	5/5 = 1	Pass
2	+1	+1	+1	+1	+1	5/5 = 1	Pass
3	+1	+1	+1	+1	+1	5/5 = 1	Pass
4	+1	+1	+1	+1	+1	5/5 = 1	Pass

Appendix J

Technology Implementation of Ubiquitous Smart Learning Space Platform

The ubiquitous smart learning space platform is a concrete implementation of the USLS, a concrete application for learning stakeholders to become a new productivity tool for every learner, every learning organization, and every learning scenario in a new way of learning.

Functional Positioning

Focus on the social involved, collaboration, interaction, reality experience. USLS needs to design, allocate and share the building elements of symbiosis space, digital space, technology space and application space by keeping in mind the learning experience of the learners. Optimization of the learning space is aimed at awakening the "spirituality" of the learner, that is, the "spiritual potential and emotional-spiritual experience" of the individual (Yang Y. D, Hao Z. J, 2016)), Learners' "spirituality" needs to be stimulated through friendly interaction from the environment. Therefore, learning spaces need to form an interconnected whole to help learners build a comfortable mental environment in which to experience social involved. For example, the SKG project initiated by the University of Alachua placed great emphasis on the learner experience. Columbia University's Learning Theater program also focuses on optimizing learners' experiences with learning activities, collaborative models, and pedagogy.

Flexible and convenient. "A learning space is a place where learners meet, conversations arise, minds collide, and ideas are born, and its role is to realize its own mechanisms through the stimulation of learners' endogenous motivation and development potential." (Mitchell, G., White, B., &Pospisil, 2010) To build a convenient learning space, convenient interaction and flexible components are the key. USLS needs to support learners' learning effectively through a convenient combination of modules. Creating a flexible, multi-purpose, and multi-scenario USLS can better adapt to the learning needs of different types of learners.

Reliable and secure. Ubiquitous learning has the characteristics of learning at any time, any place, anyway, and at any pace mainly on smartphone and laptop, which requires more attention to its reliability and security in the construction of learning spaces. For ubiquitous learners, large-scale online learning, small-scale brainstorming, and group collaboration are all effective learning methods, and different learning activities, collaboration models, teaching methods and teaching organization have different requirements for reliable and secure. In addition, the USLS has high technical stability and security requirements as it is built with both mature and advanced technologies and supports the application of the latest technologies. Reliability and secure is one of the most important principles of learning space design (T. Jrg, 2004)).

Open and compatible. USLS supports learners' free choice of learning materials, activity venues and learning methods, as well as intelligent recommendations based on learners' knowledge structure and learning interests, which requires various elements to be able to realize corresponding functions in the learning space in a timely and convenient manner, so USLS needs to have open and compatible features. Compatibility is also reflected in the ability to connect and communicate with other virtual learning spaces, other learning platforms and multiple smart devices.

Updates and iterations. USLS should have the ability to iterate, which is manifested in the support of updating various spatial elements and intelligent terminals and can further enhance the performance of the space by encapsulating, inheriting, and extending various modular spatial components. This makes the USLS an open and scalable system that enables the iteration, updating through flexible top-level design.

Technology Implementation Strategy

USLS is built on top of ubiquitous network and cloud computing, to meet the functional positioning of experience-oriented, flexible, and convenient, reliable, and secure, open, and compatible, and updated and iterative, Figure J.1 gives the USLS UML system deployment diagram.

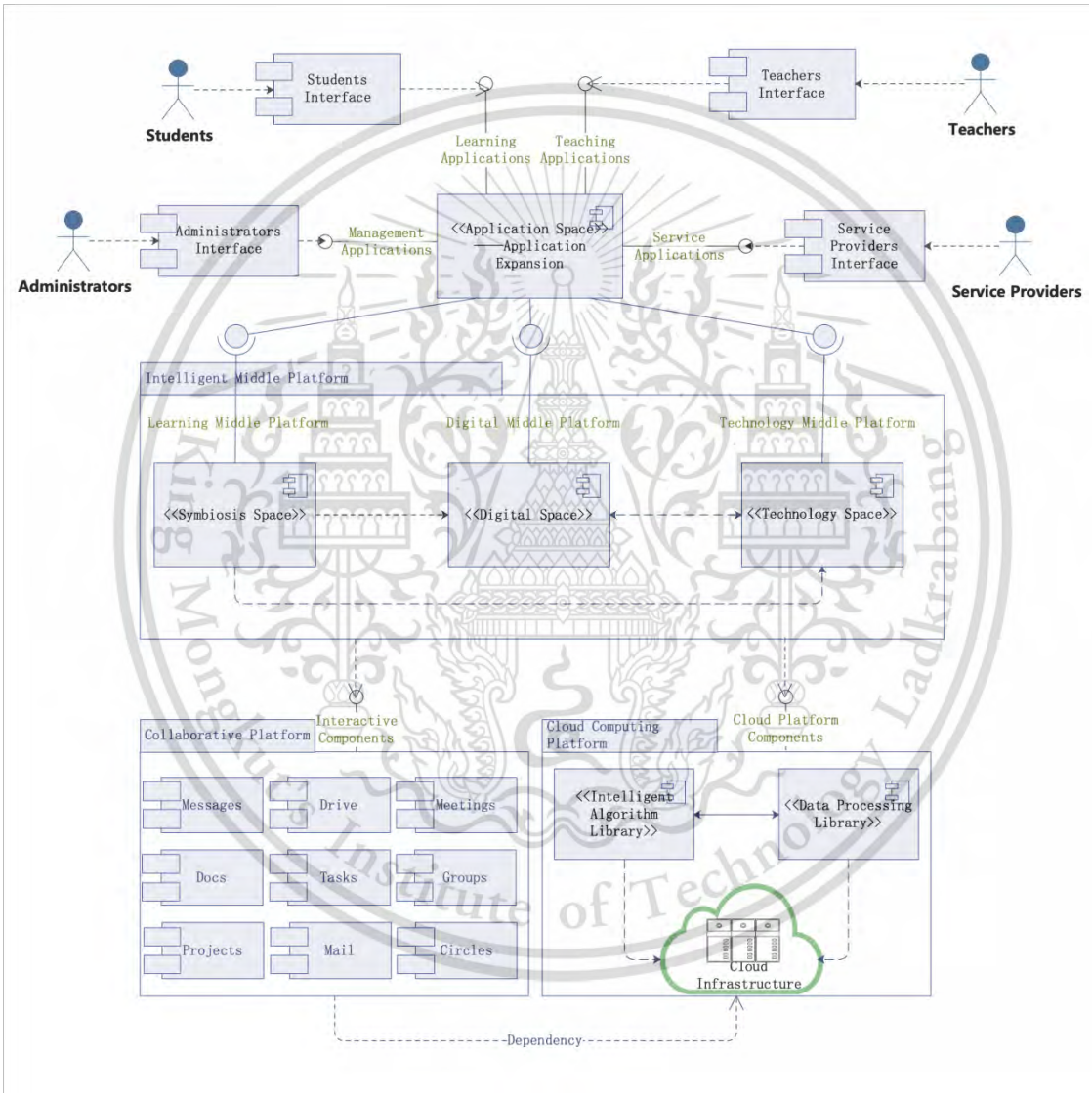


Figure J.1 USLS UML Functional Deployment Diagram

There are five specific implementations of core technologies in USLS deployments as follows.

1) Cloud computing infrastructure is the basis for the realization of the most USLS underlying, which can be used Ali cloud, Huawei cloud, Tencent cloud and Amazon, etc. The USLS technology implementation is adopted by Ali cloud.

2) The collaboration and interaction platform plays a role of carrying on the top

and bottom, which can realize efficient communication and deploy the operation interface of different learning stakeholders. The technology implementation can use DingTalk, WeLink and WeCom, etc. The USLS technology implementation is based on DingTalk of Ali Cloud.

3) Multi-experience Development Platforms (MXDPs) are tools for rapid development and deployment of applications. MXDPs are build engines in technology spaces (technology middle platform) that enable the construction of applications and the expansion of application spaces on the one hand, and the interoperability of data and processes between applications through open APIs on the other.

① Interoperability of data between USLS and external systems

External systems → USLS: External data used as USLS base data, analysis and presentation of data using USLS.

USLS → External systems: Data backup, in-depth data analysis, business notification, exception monitoring, etc.

② Interoperability of USLS with external system processes

Process-level interfacing between different systems (System A processes trigger System B processes).

Automatic trigger process (timed trigger, meet condition trigger, etc.)

③ Integration of USLS with external systems

On the one hand, after users log in to external systems (APP, self-research system, portal, smart campus platform, etc.), they can access the corresponding member accounts of USLS without secondary login, and on the other hand, they can open the address book and messaging system.

Technology implementations can use YiDa, Jiandaoyun, PowerApps and OutSystems, etc. Our implementation strategy uses AliCloud-based YiDa and Jiandaoyun, which are tightly integrated with DingTalk.

4) Application integration capability is the core content of the integration engine in the USLS technology space (technology middle platform, Zhongtai), which can be developed independently or using functions developed by third parties and others to realize the personalized needs of the space, support the needs of complex learning scenarios, and provide multi-scene, multi-purpose, and multi-role capability integration solutions.

① Create a link to an existing system as a USLS application directly through the USLS backend and publish it to the application space.

② The system within the organization is integrated with USLS login-free, so that learning stakeholders can log in with one click without an account password, making learning more convenient.

③ As an application gateway provides intranet applications with secure access to the extranet and secures data without a VPN.

④ Use connectors to enable other learning systems to quickly connect to USLS and allow for greater data flow.

⑤ Learning applications can be integrated in high-frequency collaboration scenarios such as groups, application spaces, and documents in USLS to make communication more efficient.

The technology implementation is based on Ding Talk’s rich open capabilities to manage application development, configure application information, view application operation, etc.

1) AI capability is the core content of USLS technology space (technology middle platform) intelligence engine, which is the key element to achieve the goal of " smartness". Relying on Ali's leading cloud infrastructure, big data and AI engineering

capabilities, scenario algorithm technology and years of industry practice, the technology implementation provides USLS with a cloud-native AI capability system to help improve AI application development efficiency and stimulate learning value.

① Vision Intelligence, a comprehensive vision AI capability platform that provides high ease of use and pervasive vision API services to help USLS quickly build application capabilities for vision intelligence technologies.

② Intelligent Speech Interaction (ISI) is based on speech recognition, speech synthesis, natural language understanding and other technologies to give USLS an intelligent human-computer interaction experience that "can listen, speak and understand you" in a variety of practical learning scenarios.

③ Optical Character Recognition (OCR) converts text information in pictures into editable text, meeting many types of picture recognition needs according to various learning scenarios and needs.

④ Natural Language Processing (NLP), the core tool provided for text analysis and mining, has a wide range of applications in various learning scenarios.

⑤ Machine translation relies on the leading natural language processing technology and the advantages of massive Internet data to help learners cross the language gap, enjoy communication, and access to information, and achieve barrier-free communication.

⑥ Intelligent Open Search is a one-stop intelligent search business development platform built by a large-scale distributed search engine, which provides fully open engine capabilities through built-in query semantic understanding and machine learning sorting algorithms for various industries to help developers quickly build intelligent search services with higher performance and higher search baseline effects.

⑥ Intelligent Recommendation (AIRec) provides personalized recommendation services based on Alibaba's leading big data and artificial intelligence technologies, combined with its accumulation in various industry sectors such as education, e-commerce, content, news and information, live video and social.

Combining the above analysis and design, we implemented the Ubiquitous Smart Learning Space platform, and the USLS implementation interface diagram is given in Figure J.2.

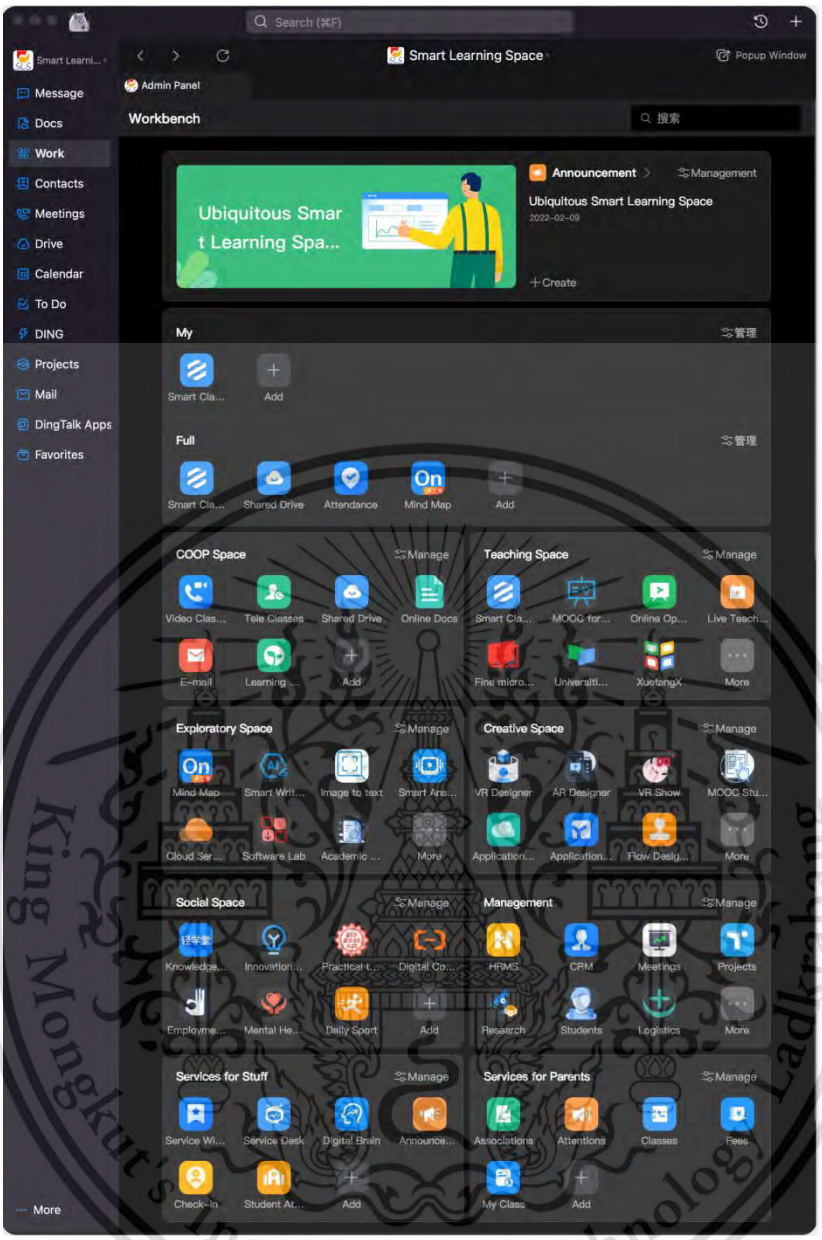


Figure J.2 USLS Implementation Interface Diagram

USLS Implementation – Take Symbiosis Space as An Example

The symbiosis space is an important component of the ubiquitous smart learning space and a learning place for learning stakeholders, consisting of a total of seven subspaces, such as interactive space, collaborative space, transmission space, creative space, inquiry space, social space, and private space. Figure J.3 gives components diagram of the symbiotic space implementation.

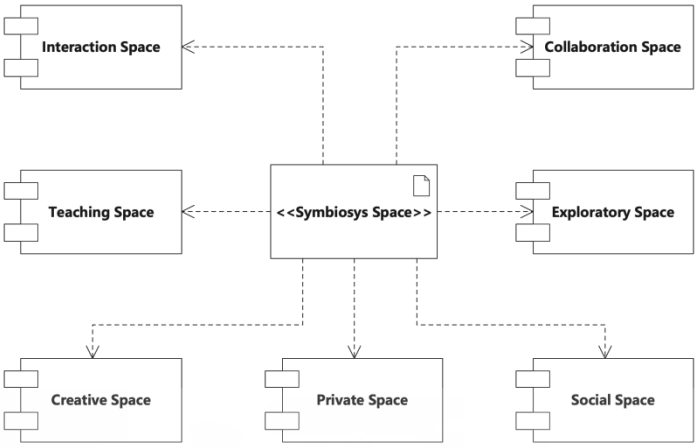


Figure J.3 Symbiosis space components diagram

Interactive space

Interactive learning is an interactive way of learning that works for learners through dynamic (verbal-based) interaction in an interactive relationship to achieve the purpose of learning. The interactive space fully supports a wider range of interactive learning methods, mainly video and voice, supplemented by tools such as instant communication, message bidding, online translation, and efficient conferencing, where learners can bring their respective cognitive characteristics into play and argue, help each other, prompt each other, or divide the work to achieve understanding and comprehension of the learning content. Figure J.4 gives components diagram of the interactive space implementation, and Figure J.5 gives a partial interface diagram of the interactive space implementation.

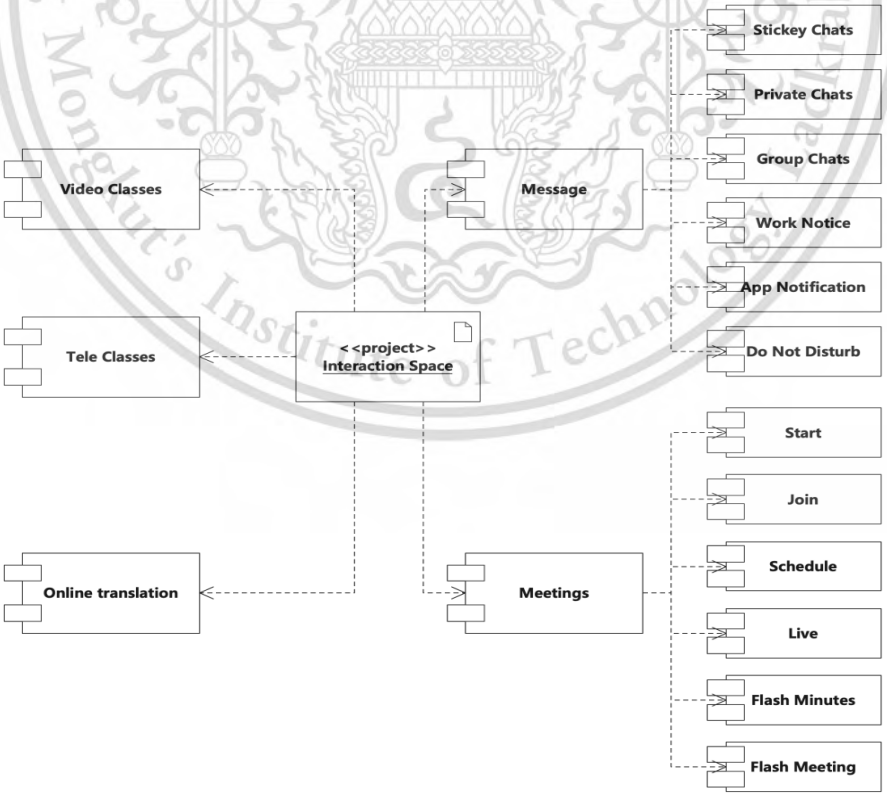
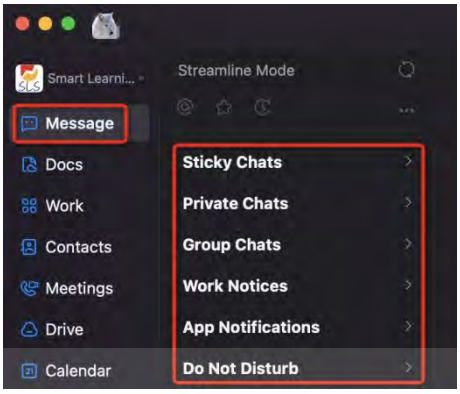
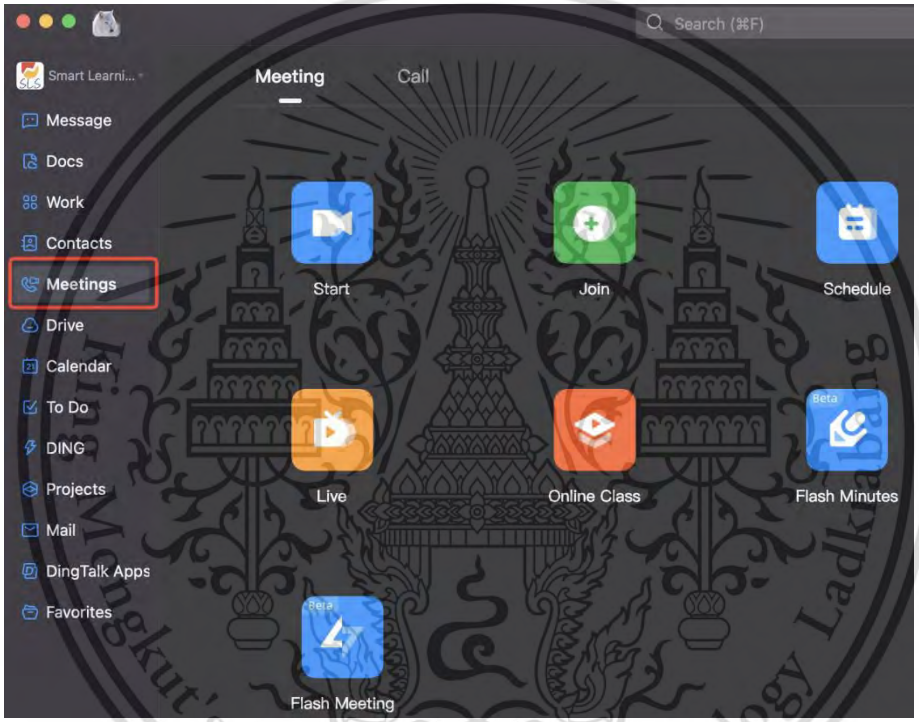


Figure J.4 Interactive Space Implementation Components Diagram



Messages

Online Translate



Meetings

Figure J.5 Partial Interface Diagram of The Interactive Space Implementation

Collaborative space

Collaborative learning is a learner-centered approach to maximize individual and group learning outcomes under a certain goal-incentive mechanism, and all related behaviors to cooperate and help each other (T. Jrg, 2004). Five key elements that influence collaborative learning are active interdependence, face-to-face facilitated communication, individual and group responsibility, interpersonal and group skills, and group reflection. Collaborative spaces are based on collaborative learning, with online documents, learning circles, shared storage, email, and project management as tools, and have unique advantages for developing learners' teamwork, communication skills, problem-solving skills, and critical thinking (Johnson, D. W., & Johnson, R. T. 1999). Figure 6.6 gives components diagram of the collaborative space implementation, and Figure 6.7 gives a partial interface diagram of the collaborative space implementation.

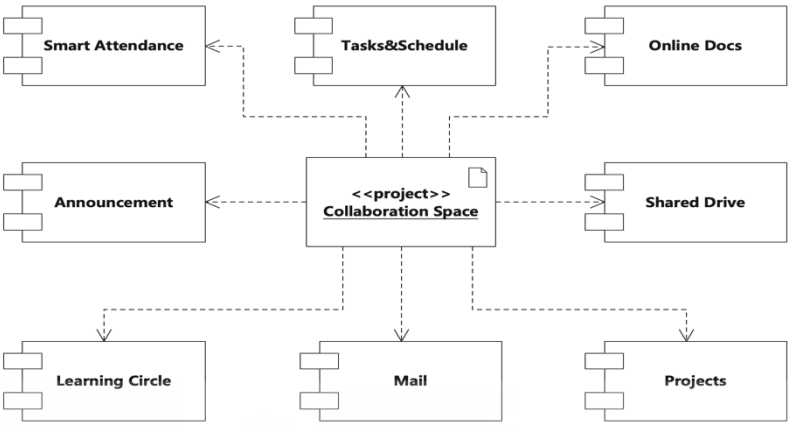


Figure J.6 Components Diagram for Collaborative Space Implementation

Figure J.7 Partial Interface Diagram of The Collaborative Space Implementation

Teaching space

The teaching space is the center for teachers' teaching and students' independent learning. Teachers can teach through live streaming, recording, online courses, MOOC courses, flipped classroom, micro-lessons, etc. Students can also learn with the above tools without the limitation of time, place and space, complete assignments, take exams, get credits, and achieve their learning goals according to their needs. Figure 6.8 gives

components diagram of the teaching space implementation, and Figure J.9 gives a part of the interface diagram of the teaching space implementation.

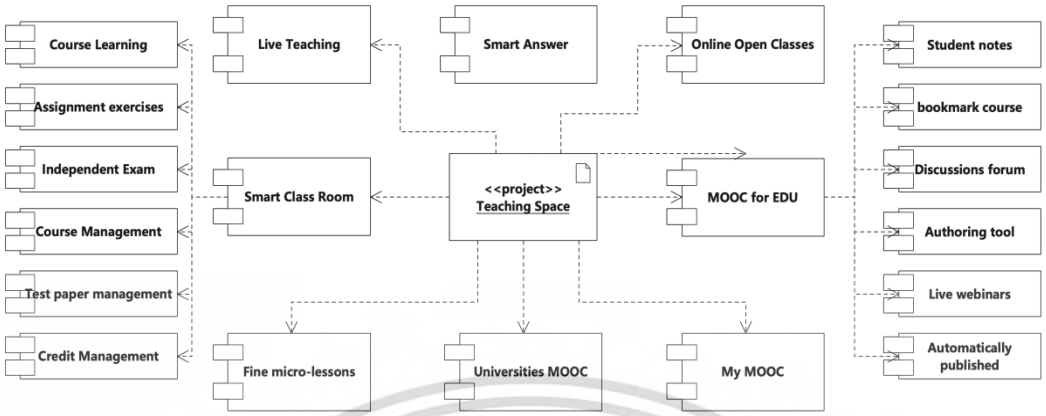
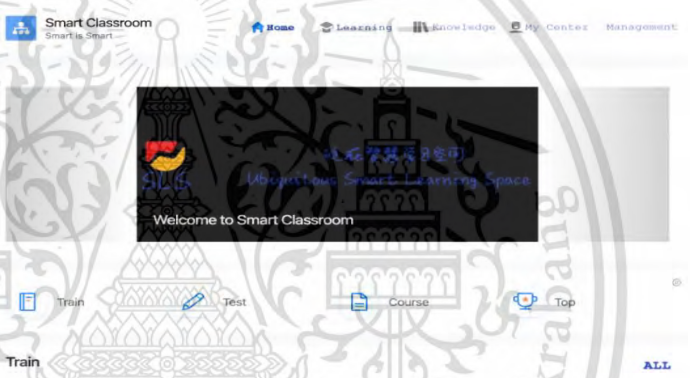


Figure J.8 Components Diagram of The Teaching Space Implementation

Teaching Space



Smart Classroom

Live Teaching

Figure J.9 Partial Interface Diagram of The Teaching Space Implementation

Exploratory space

The exploratory space is a research and exploration space for learning stakeholders. The space incorporates common tools such as mind mapping, intelligent writing, image recognition, digital technology labs, academic search, and digital shared resources to help learners improve their ability to focus on problems, investigate causes, reason, and clarify issues. Figure J.10 gives components diagram of the exploratory space implementation, and Figure J.11 gives a partial interface diagram of the exploratory space implementation.

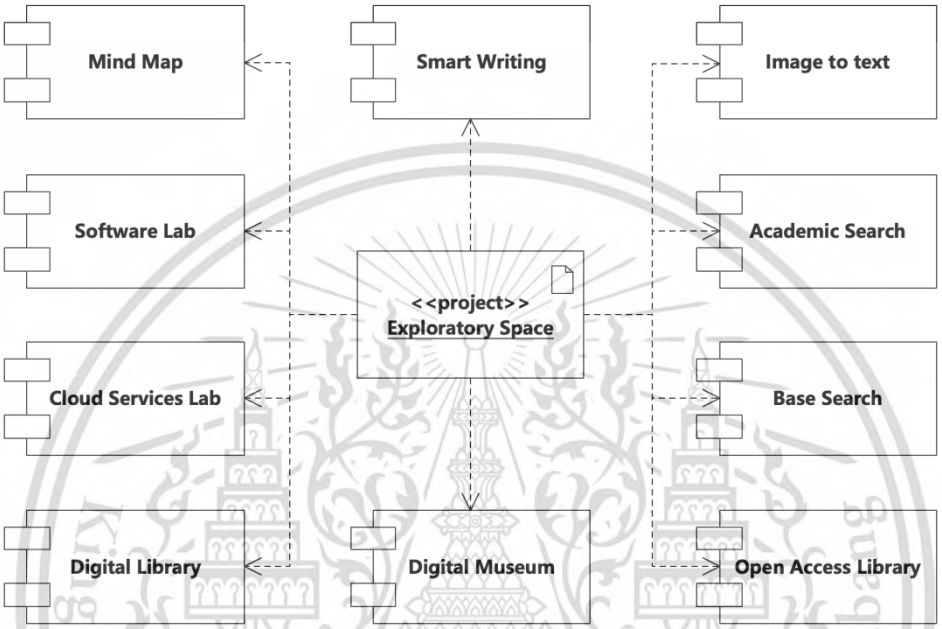
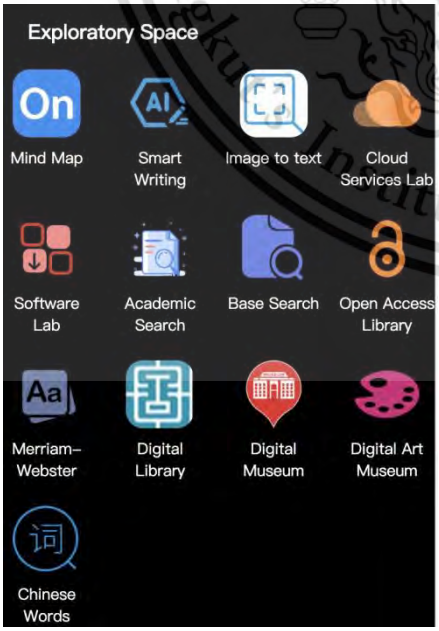
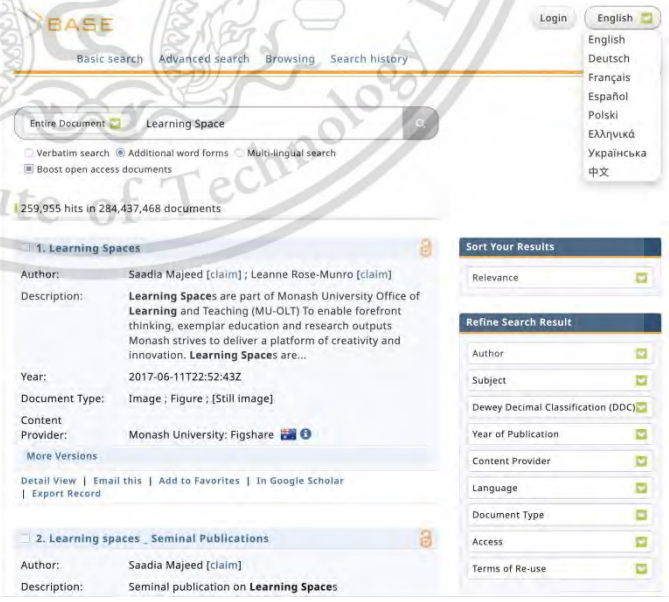


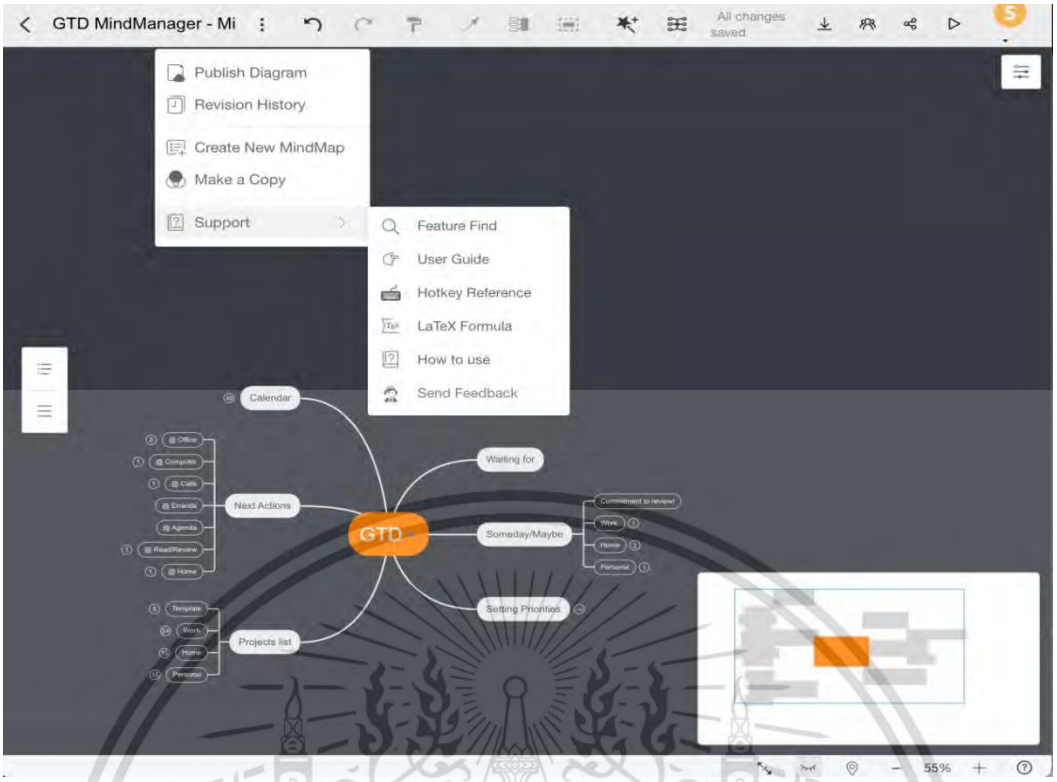
Figure J.10 Components Diagram of The Exploratory Space Implementation



Exploratory Space



Base Search



Mind Map

Figure J.11 Partial Interface Diagram of The Exploratory Space Implementation

Creative space

The Creative Space is a space for learning stakeholders to play their imagination and cultivate their creativity. The space integrates creative expansion tools such as AR/VR design, MOOC creation, form design, process design, BI design, application construction and development, etc. to awaken learning stakeholders' motivation to learn and innovate. Figure J.12 gives components diagram of the creative space implementation, and Figure J.13 gives part of the interface diagram of the creative space implementation.

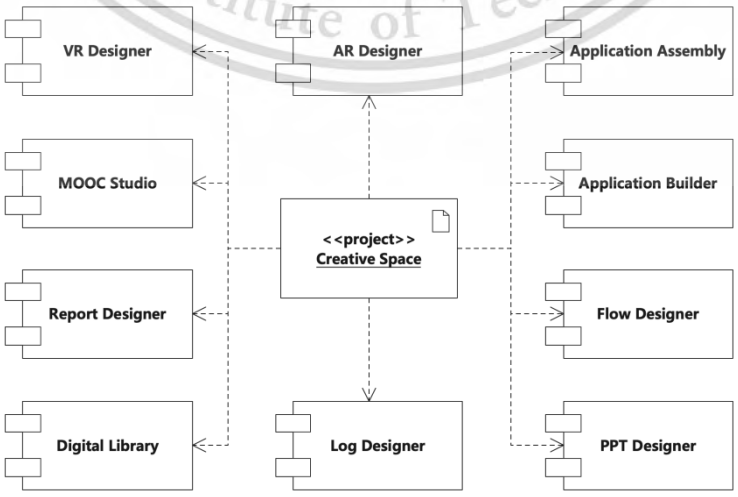
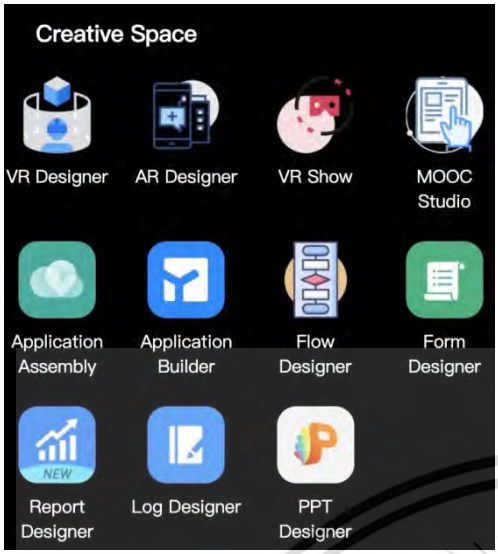
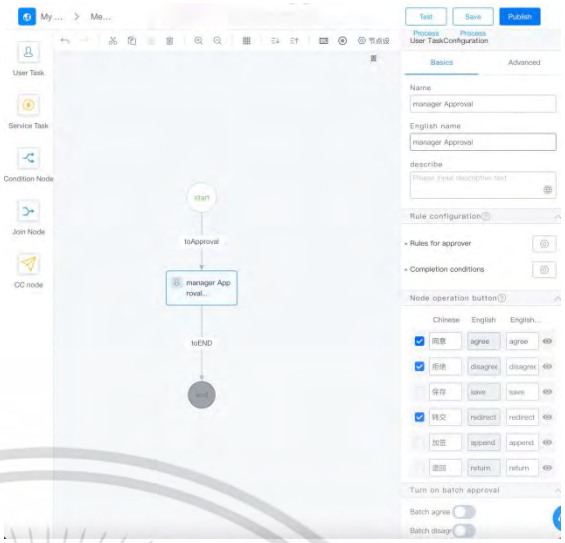


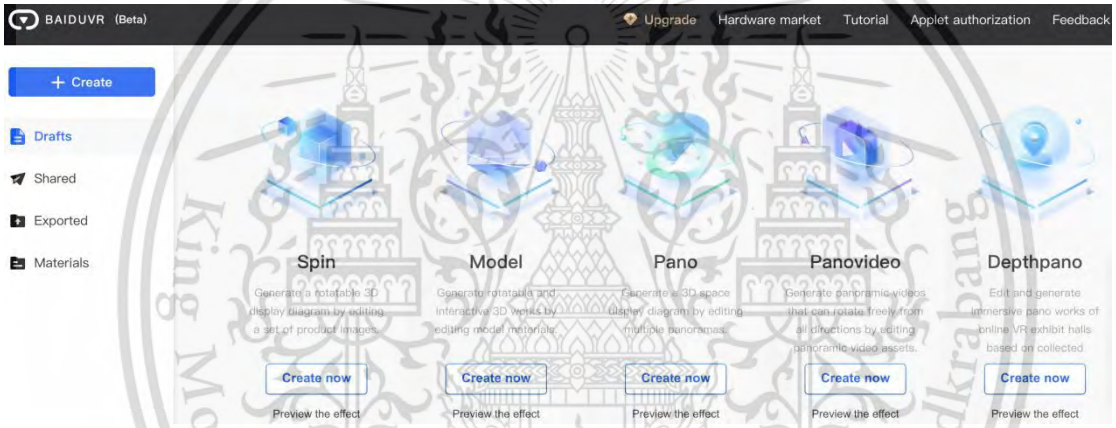
Figure J.12 Components Diagram Of Creative Space Implementation



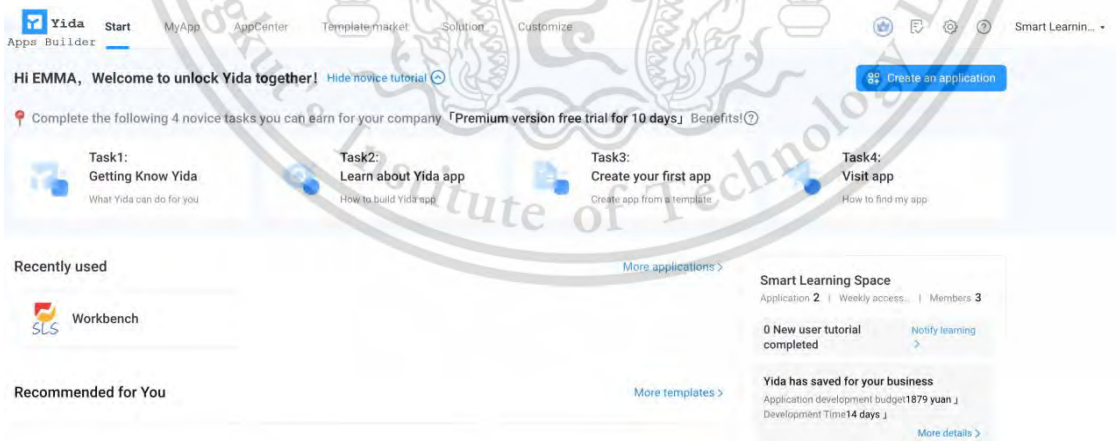
Creative Space



Flow Designer



VR Designer



Application Builder

Figure J.13 Part Of The Interface Diagram of The Creative Space Implementation

Social space

Social learning refers to the facilitation of knowledge acquisition, sharing, and behavioral improvement for individuals, teams, and organizations through social media.

Based on social learning, social space integrates learner goal-driven, content- and solution-oriented knowledge services with social elements such as internships, practical training, competitions, employment, psychology, and sports, breaking the spatial limitations of learning, not being confined to the classroom, not being fixed in the classroom, and going into the society and learning in real life. Figure J.14 gives a component diagram of the social space implementation, and Figure J.15 gives a part of the interface diagram of the social space implementation.

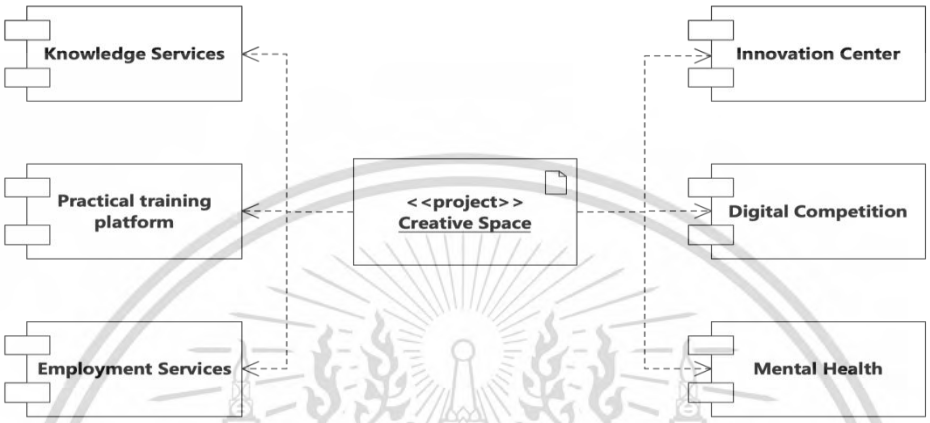
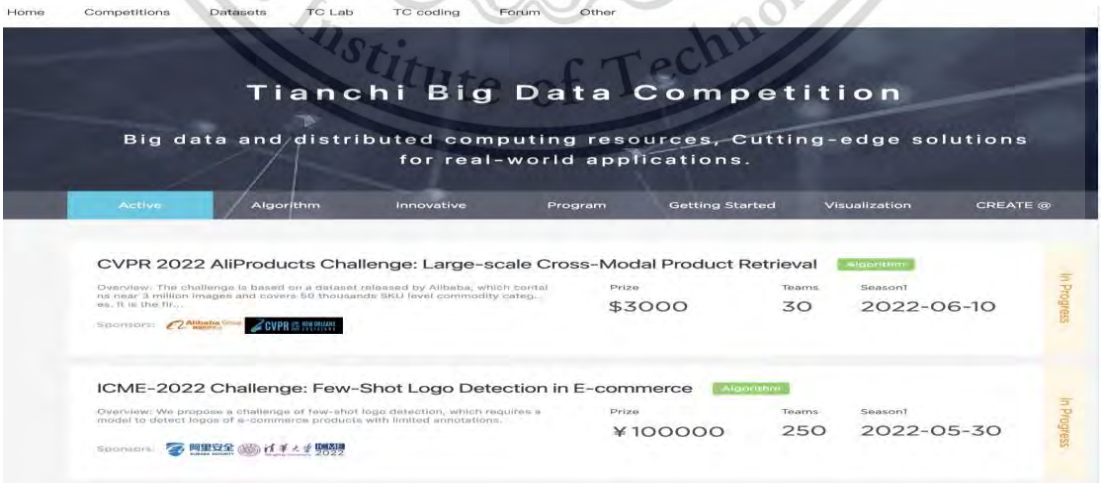


Figure J.14 Components Diagram of Social Space Implementation

Social Space

Employment Services



Digital Competition

Figure J.15 Part of The Interface Diagram Of The Social Space Implementation

Private space

The private space is a personal space for learning stakeholders, which integrates personal storage, personal knowledge base, personal circle, secret chat, private sharing and mental health and other personalized tools to support learning stakeholders to manage their own resources completely. FigureJ.16 shows components diagram of the private space implementation, and Figure J.17 shows part of the interface diagram of the private space implementation.

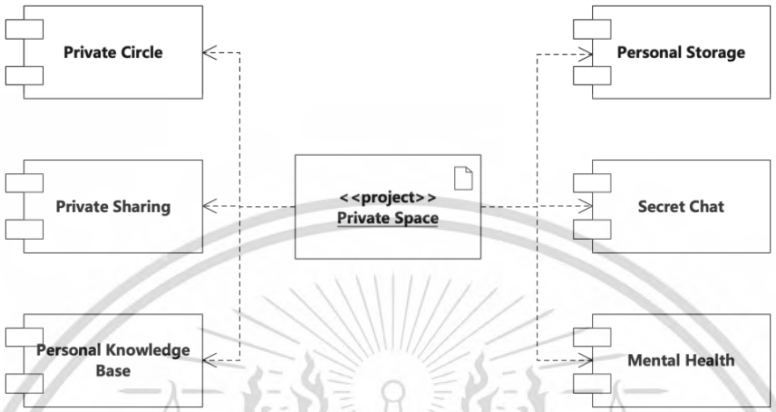
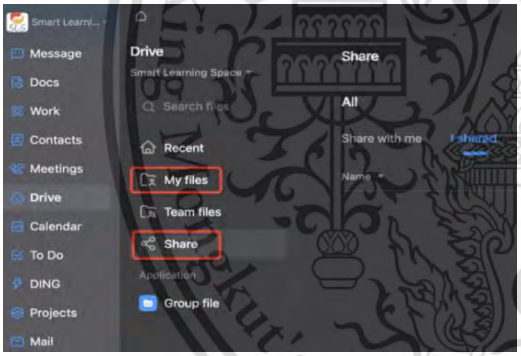
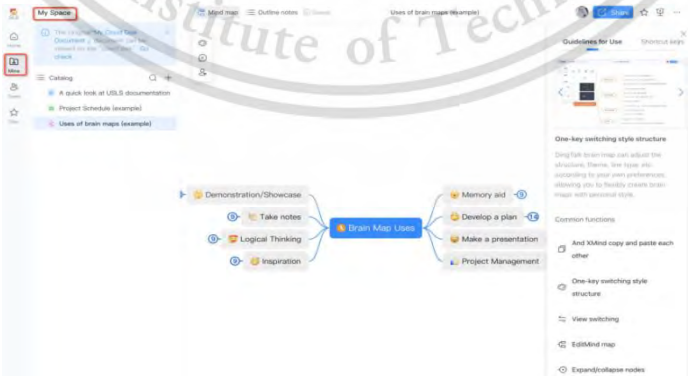


Figure J.16 Components Diagram of Private Space Implementation



Personal Storage/Sharing

Secret Chat



Personal Knowledge Base

Figure J.17 Part Of The Interface Diagram of The Private Space Implementation

Summary

The implementation of the ubiquitous smart learning space platform is built on top of the ubiquitous network and cloud computing, with features such as centering on the learning experience of learners, supporting convenient interaction and flexible components, strong practicality and reliability, better compatibility and openness, and supporting updates and iterations, which can better adapt to the learning needs of different types of learners, improve the learning experience, optimize support services, and support practical participation, and ultimately achieve It can improve the learning experience on collaboration, social evolvement, creation and immersing, optimize support services, and support practical participation, and ultimately achieve the improvement of learners' quality of thinking, development of learning ability, and stimulation of creative potential.

It is important to note that future learners have diverse thinking skills, and are integrated and unified with intensive thinking, platform thinking, and technological thinking. Learners rely more on external memory and knowledge systems to help them deal with various learning problems and issues, so the conditions for the efficacy of the ubiquitous smart learning space are comprehensive, requiring not only the support of technology, but also the scientific application of education and teaching theories. In the future, ubiquitous smart learning spaces should build learning contents according to learners' thinking, focus on highlighting their functions such as intelligent services, accurate prediction, whole-life monitoring, and emotional computing, integrate the latest advances related to digital twin, virtual native and virtual-real integration, and explore diversified and targeted strategies for teaching models in ubiquitous smart learning spaces.

Appendix K

Activities Diagrams with Ubiquitous Smart Learning Space Platform

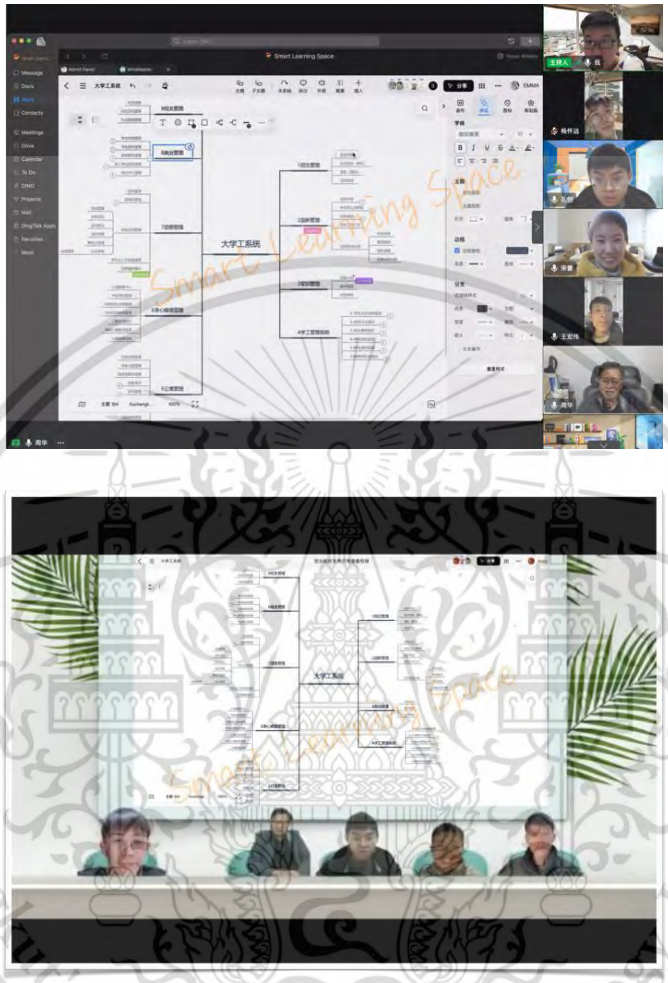


Figure K.1 Virtual Classroom Collaboration In USLS

Figure K.2 Real Learning Address

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