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ADAPTIVE MICROLEARNING: AN EMPIRICAL STUDY AMONG THE STUDENTS IN THE RURAL AREAS OF CHINA

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ADAPTIVE MICROLEARNING: AN EMPIRICAL STUDY AMONG THE STUDENTS IN THE RURAL AREAS OF CHINA

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ABSTRACT

ADAPTIVE MICROLEARNING: AN EMPIRICAL STUDY AMONG THE STUDENTS IN THE RURAL AREAS OF CHINA

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Dissertation supervised by Misook Heo, Ph.D.

Through multiple educational reforms, China has pursued developing well-rounded learners with solid content knowledge, higher-order thinking skills, and the ability to transfer knowledge to real-world problem spaces. The imbalance of learning resources between urban and rural China, however, has caused disadvantages for learners in rural China to gain access to quality educational opportunities necessary for becoming well-rounded learners. Luckily, the quickly growing Internet service coverage in rural China makes educational interventions possible. Online intervention aiming for many qualities of well-rounded learners, such as deeper learning, is particularly promising.

The purpose of this study was to investigate the potential of adaptive microlearning to improve deeper learning among public school students in rural areas of China. More specifically, this study investigated whether learners experienced deeper learning while engaging in a prototype adaptive microlearning module (Teaching Cell) to

supplement traditional Chinese classroom learning. Teaching Cell adopted the deeper learning principles from Wickersham and McGee's framework (2008).

The findings from quantitative data indicated that the Teaching Cell fulfilled many DLPs. For example, evidence supported the active learning principle, the engaged learner principle, the learner ownership principle, and the engaged activities principle. Mixed evidence was also found for the technology-supported principle, the intuitive design principle, and the facilitative teaching practices principle. However, there was a lack of evidence supporting the learner context principle. The findings from qualitative data were generally similar to the ones from quantitative data.

The current proof-of-concept study demonstrated the potential that adaptive microlearning, promoting deeper learning, has for improving the educational experience of rural Chinese public school students. While the study was designed in search of a way to help disadvantaged students from rural China, the study can be extended to assist students in urban China, as the government recently banned private companies from offering tutoring services for core subjects.

DEDICATION

I would like to dedicate my dissertation to my mother, as well as my dear daughter, Zoe, and cherished son, Lucas. May you always love what you do, never hesitate in what you choose, and always insist on making your dreams come true.

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Chapter 1

Introduction

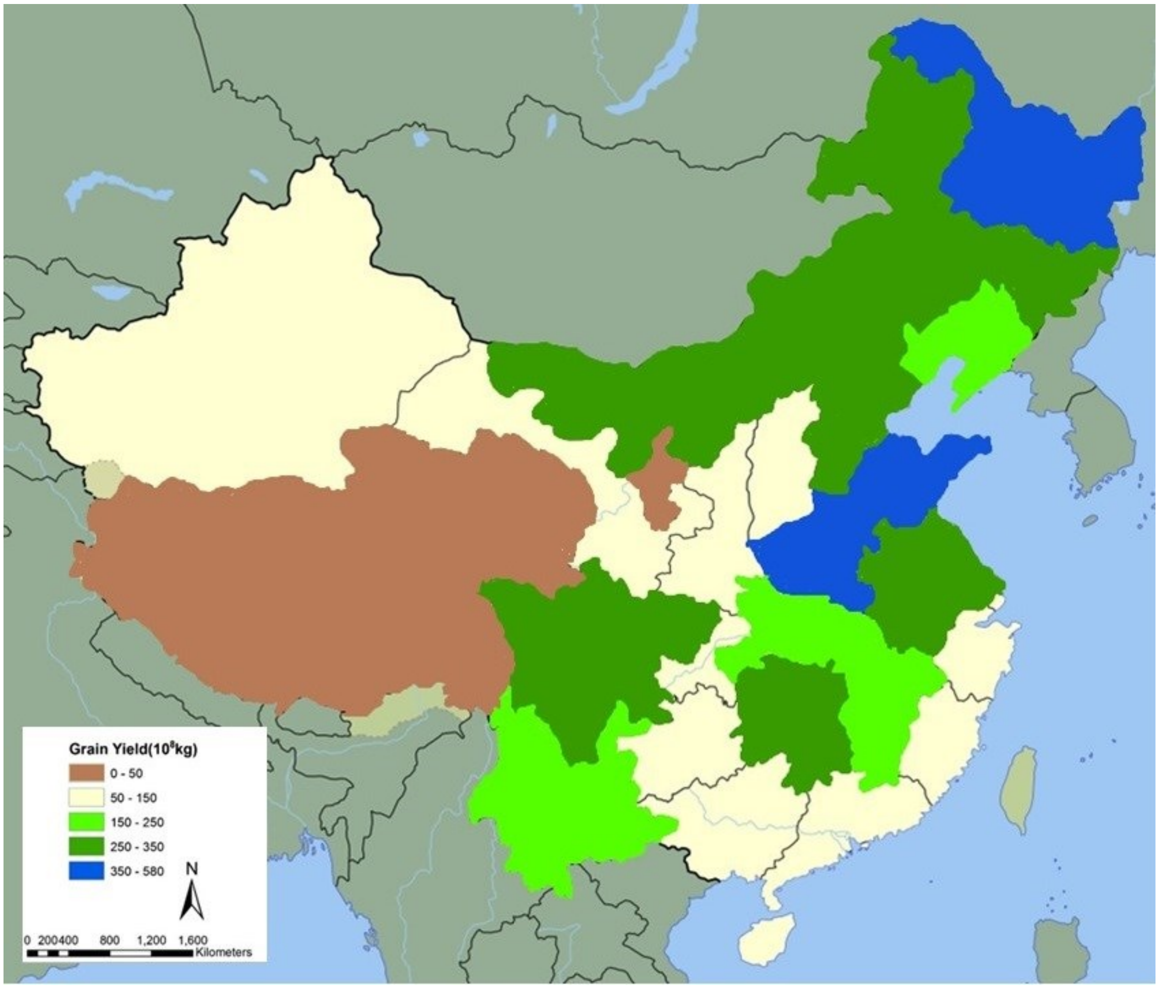
China is a large country with much geographic diversity. Understanding the background and historical development of China, thus, may help in understanding the issues and opportunities the country is currently facing in the education area.

The Natural Regionalization Work Commission in 1956 marked the beginning of regionalization in China (Fu & Pan, 2016). At the time, the objective of such regionalization was to meet the demands of agricultural development that was gearing towards full-scale urbanization (Fu & Pan, 2016) to attract foreign investment, and to promote regional economic growth (Zhang & Xu, 2017). Regionalization, however, created economic, social, and environmental issues such that financial investment became concentrated into the urban areas, and as a result, halted the development of Chinese rural areas (Zhang & Xu, 2017). Taking China's gross domestic product (GDP) as an example, in 2009, the primary industry in China, which is extraction of raw materials, made up 10.3 percent of GDP, while secondary industries (which include manufacturing) and tertiary industries (which include services) made up 46.3 percent and 43.4 percent of GDP respectively (Liu, Yang, et al., 2014). While similar proportions were observed in provinces where both urban and rural areas co-exist, such as the Shangdong province (where the distribution of primary, secondary, and tertiary industries responsible for GDP was 9.5 percent, 55.8 percent, and 34.7 percent, respectively), in other provinces with more or entirely rural areas, the shares of GDP devoted to secondary and tertiary industries were likely to be much lower (Liu, Yang, et al., 2014).

Despite the booming economic growth, as a consequence of urban-centered development, China remains mostly agricultural, especially in the western region. The grain yield and water quality in China shows an example of this discrepancy. Compared to the West, where the process of urbanization has shown greater promise, the East and the North have much higher grain yield and better water quality (see Figure 1). The fact that the West remains agricultural contributes to its ongoing poverty (Lu et al., 2015). These agricultural regions, however, cannot be simply developed into urban areas, as China has to mitigate the increasing pollution issue caused by urbanization (Lu et al., 2015).

Figure 1

Distribution of Grain Yield in China in 2010. Adapted from Lu et al. (2015)



Less-developed infrastructures in rural areas of China are responsible for the lower productivity in the western region (Ansar et al., 2016). One reason for the limited infrastructure in this region is geographical. As the western areas of China are mainly desert, it is difficult to build a road system (Qiao et al., 2014). Building roads in these areas, however, could allow people from the region to participate in off-farm employment activities which could lead to higher wages and less poverty (Qiao et al., 2014).

Expanding communications in rural areas is also vital for economic growth as seen in the case of Anshan. Anshan, a rural town in northern China, began to build an infrastructure around what is called “rural informatization” in the mid-2000s. From 2005 onward, Anshan experienced not only the increased availability of information communication technology and reductions in telecommunications cost, but also economic improvement. Although this type of expansion in connectivity continues (iResearch Consulting Group, 2018), it is not consistent throughout all Chinese rural areas.

Lack of infrastructure regarding education, science, and technology in the western region of China has been widely criticized (Ansar et al., 2016). As the rural area in China remains impoverished, their educational systems continue to lack the resources necessary to be functional. For example, children from rural villages in Gansu province in the southwest suffer from a high prevalence of food insecurity and poor nutrition, and this high level of poverty negatively affects how children perform in school (Hannum et al., 2011). Among the many educational challenges faced by these rural students is the high cost of tuition, such that many students cannot afford it (Chyi & Zhou, 2014). Research shows that when poor, rural Chinese children received free textbooks, a tuition waiver, and living expense subsidies, their school enrollment rate indeed improved (Chyi & Zhou, 2014). These subsidies are necessary to improve school attendance because otherwise, children are forced to assist the family by working on the farm, a situation recognized as the “rural education gap” (Miao & Wong, 2014). Subsidizing tuition for students in rural areas was reported save rural families 13.8 percent of their income (Lü, 2014).

Statement of the Problem

Since public education became compulsory and was funded by the government in China in 1986 (Hannum et al., 2011), its examination-oriented system has continuously been a concern, and has instigated a sizable underground tutoring economy (Kwok, 2010). The extremely high student-to-teacher ratio in public education in China, however, makes it difficult for teachers to offer sufficient personalized support for students. Rural Chinese students have to face greater barriers to education in public schools compared to their urban counterparts, as the quality of the teachers in rural areas is often less than optimal (Sicular et al., 2007). Individualized learning is particularly absent in rural areas in China, and the lack of tutors in rural areas also contributes to the worsened educational conditions in these areas (Zhang, 2013). Rural students are thus facing a higher dropout rate, low teaching quality, and a lack of opportunities for tutoring. Only 52.6 percent of junior secondary graduates in the rural area are allowed to continue in senior secondary school in China, and this can have a lifelong impact (Dello-Iacovo, 2009).

Interventions have been proposed to address the rural-urban education gap in China. For example, the *Go West* program involves sending leading college graduates to rural areas by providing tax benefits and other incentives to develop the region; some serve directly as teachers (Miao & Wong, 2014). Non-governmental organizations such as *Our Free Sky* have also provided qualified teachers to China's rural areas (Miao & Wong, 2014). Rural residents, however, continue to demand better access to high-quality public education and are expecting the government to support this (Lü, 2014).

Great potential lies in the fact that internet service coverage is growing quickly in the rural areas of China (Li et al., 2014), as the Internet can provide rural students with much-needed personalized learning opportunities. Various conceptual and technological advancements contribute to the potential of personalized online learning in the rural areas in China, and these include adaptive learning, microlearning, and deeper learning.

Adaptive Educational Hypermedia Systems (AEHS) aim to improve the learner's comprehension and uptake of the educational material by providing the learner with multiple pathways containing learning activities tailored to their specific learning characteristics and preferences (García & Flores, 2008). It has been observed that AEHS's have not been widely adopted because such systems face many technological and practical challenges (García & Flores, 2008). However, as technology has improved, using an AEHS framework has become more possible. More recent advances allow for the incorporation of micro-adaptivity within such a system (Kickmeier-Rust & Albert, 2010). Kickmeier-Rust and Albert (2010) observed that the type of micro-adaptivity that is seen in electronic games, where each user interaction changes the digital environment, could be leveraged for more effective digital learning. Micro-adaptivity adjusts 1) the look and feel of the learning environment according to the student's preference and needs, 2) curriculum sequencing according to the student's learning goals and prior knowledge or learning experience, and 3) problem-solving support delivered with detailed individualized feedback about the student's performance (Kickmeier-Rust & Albert, 2010) to address the unique needs of each student.

Microlearning is a learning formula that combines micro-content delivery with a sequence of micro-interactions which enable students to learn without information overload by offering small doses of content, while empathizing user interactions. The essential idea of microlearning is that knowledge is much more digestible when consumed in smaller doses rather than large chunks, a concept in stark contrast to the traditional practice of Chinese education system (Chan & Rao, 2010). Empirical data from a study of microlearning show its potential to support personalized learning: 81 percent of microlearning participants reported believing that microlearning modules are integral to the development of a personalized learning environment (Job & Ogalo, 2012).

Deeper learning emphasizes the process of learning to allow learners to transfer their new knowledge into novel situations (American Psychological Association, 1997; Johnson & Lomas, 2005; McGee & Wickersham, 2005). Deeper learning aims to help students develop a growth mindset through critical thinking, teamwork, and metacognition to master rigorous academic content (McGee & Wickersham, 2005). As such, deeper learning encourages students to actively explore, reflect, and produce knowledge (i.e., active learning) rather than undergo rote memorization (Wickersham & McGee, 2008). With deeper learning comes the possibility of developing a well-thought-out system of support for personalized learning, which could provide learner access to a deeper level of knowledge beyond a superficial level of learning. Studies have shown that students who are engaging in deeper learning demonstrate the desire to participate in their learning in a meaningful way, tend to solve academic problems with a diverse set of solutions, and conceptualize their topic of study better (Biggs, 1999).

With the quickly-expanding internet service coverage in Chinese rural areas, online educational platforms can be leveraged to promote deeper learning, especially for personalized learning, and can be used to supplement learning outside of the classroom (Lamb & Annetta, 2013). In fact, personalized, self-paced online teaching modules have been associated with improved teaching quality in terms of collaborative and rigorous learning in rural classrooms in the United States (US) (Luebeck et al., 2015). Developing an online adaptive microlearning module approach to foster deeper learning in rural Chinese public school students would leverage the advancing internet infrastructure and could help these students increase their exam scores as well as prepare for their future lives.

Since 2001, China has been active in education reform to bring about "quality education" (i.e., *suzhi jiaoyu*), which emphasizes well-rounded student development while moving away from examination-oriented education (i.e., *yingshi jiaoyu*) (Chyi & Zhou, 2014; Dello-Iacovo, 2009). A document presented to the Chinese Ministry of Education stated that the purpose of reform is to promote students' active participation in education through encouraging independent inquiry, increasing practical abilities, and having students practice problem-solving skills and teamwork (China Education and Research Network, 2018). With the government's structured effort and public support, China has started to see fruitful outcomes. For example, China observed an increase in mathematics graduates in 2017, meeting the goal set out by Xi Jinping's "Chinese Dream," to make China a World class innovator by 2050 (Han & Appelbaum, 2018).

Purpose of the Study

The goal of this study was to investigate the potential of adaptive microlearning to improve deeper learning among the public school students in the rural area of China. More specifically, this study investigated the deeper learning experience of learners who engaged in adaptive microlearning modules to supplement traditional Chinese classroom learning.

Research Questions

To achieve the aforementioned research goal, an overarching research question was identified: Does the adaptive microlearning module, used as a supplement, yield an improved, deeper learning experience that can supplement traditional Chinese classroom learning? To further investigate the research question and assess learners' experience, the following sub-questions were explored:

1. Does the adaptive microlearning module promote the learner engaging in *active learning*?
2. Does the adaptive microlearning module inspire the learner to create *learner context*?
3. Does the adaptive microlearning module create an *engaged learner*?
4. Is the adaptive microlearning module associated with *learner ownership*?
5. Is the adaptive microlearning module an example of *technology-supported learning*?
6. Is the adaptive microlearning module an example of *intuitive design*?
7. Does the microlearning module lead the learner to participate in *engaged activities*?
8. Is the adaptive microlearning module associated with *facilitative learning practices*?

Significance of the Study

This research contributes to the literature with empirical evidence to what extent adaptive microlearning is associated with deeper learning in public school students in the rural area in China. This research will be able to help further research on the role of instructional technology in deeper learning, and studies on adaptive learning using large datasets and learning analytics to improve students' learning outcomes.

As for contribution in practice, the adaptive microlearning module aims to provide the kind of individualized instruction that a good quality tutor might facilitate, which otherwise is unavailable to many rural Chinese students. As such, if the study findings show the module does promote a deeper learning experience, this approach could be expanded and improve rural students' learning capacity and competitiveness both academically and in their future lives. This could be accomplished through the use of the microlearning module by independently allowing the learner to establish a growth mindset, and continuously gain metacognitive awareness with more profound and meaningful relationships with learning. Moreover, this research could also help to establish a new orientation of Chinese online education and support educational reform. For example, by adopting the adaptive microlearning approach for deeper learning, teachers could be trained to be more independent and empowered for course development, which would help them be more creative and have the authority to manage their work. Schools could also benefit as they could develop a well-rounded knowledge base and high-quality curricula that could improve student metacognition. The improved curricula, then, could move the pedagogy from historically teacher-centered to student-centered and promote more interaction and communication in class.

Definition of Terms

Active learning: A type of deeper learning involving solving real-world problems, inquiring about and analyzing new ideas, creating items through learning activities, and collaborative learning (Wickersham & McGee, 2008).

Adaptive learning: Adaptive learning is where teachers to collect and analyze student learning data and consequently adjust instructional contents to make sure they achieve desired benchmark learning outcomes according to established assessments (Aleven et al., 2016).

Adaptive microlearning prototype: A prototype containing a series of microlearning modules with adaptive features so that the learner's experience of the prototype changes as it adapts to their input from the various microlearning elements (Aleven et al., 2016; Chan & Rao, 2010; Liu & Kush, 2015).

Deeper learning and deeper learning principles: Deeper learning is the process of preparing and empowering learners to master critical academic content, engage in critical thinking, solve complex problems, work collaboratively, communicate effectively, assume an academic mindset, and engaging in their education in a self-directed way (Martinez & McGrath, 2014). Deeper learning principles are a set of principles that are put forward to form a framework to guide development of deeper learning curricula (Carmean & Haefner, 2002; Wickersham & McGee, 2008).

Engaged activities: A type of deeper learning involving making public contributions of learning products, collaborating and cooperating on learning activities, and having the opportunity to apply, synthesize, and evaluate learned knowledge.(Wickersham & McGee, 2008).

Engaged learner: A type of deeper learning involving having the learner be able to choose how to learn and set specific goals or objectives for learning.(Wickersham & McGee, 2008).

Facilitative learning practices: A type of deeper learning where learning materials are responsive to learner to accommodate the learner, and allow the learner to engage in activities of purposeful knowledge negotiation and acquisition (Wickersham & McGee, 2008).

Intuitive design: A type of deeper learning where learning materials are intuitive in terms of navigation and usability, include multi-modal content options, have clear criteria for performance and completion, and are accessible to those with disabilities (Wickersham & McGee, 2008).

Learner context: A type of deeper learning involving having learners choose what to learn from different learning models, engaging in higher order evaluation, and being allowed to choose activities that build on existing skills and knowledge(Wickersham & McGee, 2008).

Learner ownership: A type of deeper learning involving giving the learner the opportunity to set goals and timelines, to be able to choose the format of end-products, and to identify problems, processes and solutions (Wickersham & McGee, 2008).

Metacognition: The ability for one to engaging in reasoning about one's own cognitive processes, and to modify one's own behavioral and environmental functioning in response to the demands one faces (Veenman, 2017).

Microlearning module: A miniature learning module developed to be experienced in a short session intended to deliver a small amount of instruction so as to prevent information overload (Chan & Rao, 2010).

Technology-supported learning: A type of deeper learning that refers to allowing the learner to be able to engage in learning in any physical setting chosen, and to choose from multimodal technological information sources, have access to both public and private online functions, and interact through a deep rather than surface interface (Wickersham & McGee, 2008).

Chapter 2

Literature Review

Education System in China

Education in China dates back from the earliest existence of human culture. For over 2,000 years, ever since the days of ancient imperial China, the central government had sponsored official school education (Dello-Iacovo, 2009). Since the beginning, formal education has revolved around the imperial examination, also called the civil service examination system (Dello-Iacovo, 2009). This history forms the basis for modern public education in China (Dello-Iacovo, 2009).

Figure 2 presents China's current education system.

Figure 2

The Education System in China

Age	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
School Year				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Preschool																									
Primary Education																									
General Junior High School																									
Upper Secondary Vocational Education																									
General Senior School																									
Vocational Senior Secondary Education																									
Bachelor's Degree																									
Higher Vocational Education																									
Master's Degree																									
Doctoral Level																									

Note. Adapted from Zhou and Zhu (2006)

As shown in Figure 2, public education in today's China includes nine years of compulsory education, which consists of six years of primary school (*xiaoxue*: grades 1 through 6) and three years of middle school (*chuzhong*: grades 7 through 9), as indicated in red and orange on the figure (Zhou & Zhu, 2006). Next, secondary education includes senior high school (*gaozhong*: grades 10 through 12) as well as vocational high school (Hannum et al., 2011). After this, the learner may opt for advanced college degrees.

Education Reforms in Modern China

Public education in China has undergone active reforms since the late twentieth century (Chyi & Zhou, 2014; Dello-Iacovo, 2009; Miao & Wong, 2014). These reforms have been generally in line with the ideal called *suzhi jiaoyu*, which is roughly translated to "quality education" (Dello-Iacovo, 2009, p. 241). *Suzhi jiaoyu* is conceptualized as a countermeasure for the excesses of examination-oriented education *(yingshi jiaoyu*) of the traditional system (Dello-Iacovo, 2009). This section chronologically summarizes China's education reforms that aimed to evolve the education system from *yingshi jiaoyu* to *suzhi jiaoyu*.

Post-1949. Since the People's Republic of China was established in 1949, the Chinese Communist Party (CCP) has controlled the country in all of its governing aspects, including media, schools, and most industries. The education institutions have been more "party-oriented", which means that as part of the curriculum, students gain political knowledge associated with the history of the CCP. This implies that the education procedures that are put in place are influenced by the political agenda of the CCP. For example, in addition to taking political courses, elementary school students are encouraged to join in the Young Pioneers of China (YPC), an organization that enrolls students from age six to fourteen. By exposing elementary students to the Communist ideology, the YPC effectively makes them pseudo-members of the Chinese communist party (Deng & Treiman, 1997).

The YPC is mandatory for Chinese youth who have undergone public education, and its ideals are reflected during the educational process. The Chinese public political education is mainly focused on imparting Marxist ideologies and the CCP history, rather than a presenting a well-rounded education that explains and describes the complex sphere of Chinese politics in a fair and unbiased manner (Tsang, 2000). As stated by Chinese officials, however, the main purpose of Chinese education is to foster not only acquisition of expertise, but also moral development of learners (Tsang, 2000). This official statement compared to the reality of the Chinese education system in how it imparts political agendas is not necessarily contradictory in nature. Nevertheless, it is important to bear in mind that the Chinese government shows a tendency of playing with words through re-directing of some of its criticisms.

Cultural Revolution period. The Cultural Revolution is one of the most devastating historical events in modern Chinese history. Launched by Mao Zedong in 1966, the Cultural Revolution was a decade-long propaganda campaign on a national scale. Although the goal of the Cultural Revolution is one of the most contested political topics by both Chinese and foreign scholars, according to the "May 16 notification" which signified the beginning of the campaign, its purpose was to implant "Mao Zedong thought" into the Chinese in order to eradicate bourgeois ideals from within the CCP (Xiaoman & Cilin, 2004).

The Cultural Revolution stands as the most substantial interruption of social, economic, and educational development in China. During the eleven years of the revolution, which took place from 1966 to 1977, China's education system was disturbed significantly; university entrance exams were canceled, and students missed schooling and educational attainment (Meng & Gregory, 2002). As was indicated in the post-1949 section above, what is said by the CCP in an official capacity can rarely be taken at its face value, especially with respect to a controversial historical event such as the Cultural Revolution. Nonetheless, the devastating effect of the Cultural Revolution has been very pronounced on modern Chinese society in the long-term.

The Cultural Revolution was said to transform Chinese society in terms of its ideology; however, the actual impact was much more grounded in reality. This primarily came in the form of social and cultural destruction, such as a halt in education, and the eradication of music and literature (Xiaoman & Cilin, 2004). One of the main proclamations during the campaign was the denunciation and purging of intellectuals and educators who were thought to represent the old values. During the process, countless teachers were imprisoned, tortured, and even executed (Wan, 1998), and as a result, education in China was virtually halted. Universities were closed down, and the literacy rate suffered (Wan, 1998). While the impact of the Cultural Revolution had a broader reach than the scope of the education system of China, it made especially relevant the subsequent efforts at reforming of the education system as a result.

Four Modernizations period. In 1977, China adopted Four Modernizations to reconstruct economy. The Four Modernizations is a series of policy implementations that aimed to direct the nation's priority and resources into the four aspects of national development: agriculture, industry, national defense, and science and technology (Ashmore & Cao, 1997). These reforms were direct responses to the social and cultural destruction caused by the Cultural Revolution, and were a means to revive the Chinese economy.

As education was considered the foundation of the Four Modernizations, reforms to the educational system were put in place. The way the examinations were structured has changed over time. For example, when the system after the Cultural Revolution was put in in 1977, there were only two educational tracks: one for arts and letters, and another for sciences and engineering (Hannum et al., 2011). Because the Culture Revolution devastated both of these fields by virtually destroying the existing education, new education policies were put in place. For example, the Arts Education Department was established in 1986 to compensate for the regression in art education made during the Cultural Revolution (Wan, 1998). This effort at educational reform came to its height during the 1980s, when China enacted the 1986 Compulsory Education Law. This law was to ensure that all students, especially in those in the poorer, rural areas who generally suffered from the gender divide in terms of education level and high illiteracy rates, complete school (Hannum et al., 2011).

The Four Modernizations was a key cornerstone in the long history of Chinese education reform, as it was one of the most profound instances when the Chinese government acknowledged the fact that education is the foundation to its national development. This acknowledgement led in turn to modern Chinese education reform and the Action Plan for Invigorating Education.

2000s. In 1999, the World Bank researched the strategic goals for Chinese education in the twenty-first century, and stated that the Chinese education system needed changes in order to produce desirable results in an evolving world. Indeed, since 2000, China has implemented many policies that are developmental strategies regarding its education system. Examples include the policy document *The Decision on the Reform and Development of Basic Education* published by the State Council in 2001, *The Rejuvenation Action Plan for Education 2003–2007* published by the Ministry of Education in 2004, and *The Opinion on the Enhancement of the Teaching Workforce* published by the State Council in 2012 (Walker & Qian, 2012). These educational policy documents focused on four themes: equality (e.g., education for every citizen), quality (e.g., improvement of education quality), efficiency (e.g., educational and human development), and rejuvenation of the nation (Law, 2014). As was advocated earlier in *The Action Plan for Invigorating Education Towards the 21st Century* by the Ministry of Education in China (Law, 2014), education had now become the top priority which was not only emphasized by the whole community, but was also treated as a strategic position by leaders.

In 2001, a basic education curriculum reform policy called the Notification of Basic Education Curriculum Reform was introduced to meet the needs of every Chinese student through sound educational development. Information Communication Technology (ICT) was emphasized in this reform to promote the modernization of education. One of the main ideas of this reform was to prepare students for college entrance during their entire school career, and therefore, the examinations should be calibrated to this goal. Accordingly, the college entrance examination structure also changed. For example, the topics tested at the exam have expanded to take the “3 + X” approach. In the approach, “3” refers to the three topics of language, mathematics, and foreign languages as compulsory subjects to test, and the “X” refers to other subjects or combinations of subjects that are required by colleges (such as physics, chemistry, and biology). Even though the reform promoted preparing students for college entrance during their entire school career, teaching remained very test-focused (Walker & Qian, 2012).

The Chinese government also launched the “New Curriculum” reforms in 2001 (Altinyelken, 2015). In order to better connect students with their local environments and to facilitate them adapting to local conditions, publishers developed many new textbooks, and textbook policy was changed accordingly (Altinyelken, 2015). At this time, the curriculum was also standardized through the offering of government-created and -managed websites describing each of the many lessons taught throughout Chinese public school education. Even with this standardization, teachers were allowed to use different textbooks and were encouraged to use diverse teaching and learning resources under the motto, “One curriculum, many textbooks” (Altinyelken, 2015). Empirical evidence suggests that while under-resourced teachers in China who have fewer academic skills rely more on textbooks and curriculum guides, better-resourced teachers are able to be more diversified and flexible (Paine & Fang, 2006). From this perspective, the New Curriculum reforms allowed teachers to use the curriculum standards as a framework from which to personalize their pedagogies and contents. These reforms also highlight the importance of student-centered teaching, and the fact that the learning environment must respond to the needs of all children (An et al., 2007).

Education Issues in China

National Examination-Oriented System. For over 1,000 years, Chinese education has centered around examinations; this approach is still standard in today's China, even after the many educational reforms in the past several decades (Ross & Wang, 2013). The modern-day Chinese education system still focuses on examinations, is disconnected from everyday life, and allows teaching styles that do not cultivate initiative and responsibility (Dello-Iacovo, 2009). The test-based system is reported to encourage dropouts (Yi et al., 2012).

This examination system affects the upper secondary and tertiary education, as not all compulsory Chinese education is seen as equal; public schools and universities are rated by the Chinese government according to published criteria (Hannum et al., 2011). For example, each students performance on the high school entrance examination (which serves as the middle school exit examination as well) changes how they are routed through the rest of the school system (Hannum et al., 2011). This is reflected in the long-standing criticisms of the Chinese education system that has root in its competitive nature. The school and university rating system has created mystification surrounding university standards, which were not only meant to establish policy initiatives but also to reestablish elite institution status (Kirkpatrick & Zang, 2011). In reality, this cultivates a mindset among Chinese students and parents that breeds competition among students to perform better in entrance exams to universities that enjoy elite status.

Teacher quality. Research shows the quality of teachers is strongly associated with student achievement (Akiba et al., 2007; Darling-Hammond, 2000). Teacher behavior also influences student engagement, as well as student perceptions of student-teacher interactions, as demonstrated in a study by Skinner & Belmont (1993). While these studies were conducted outside of China, their findings collectively emphasize the importance of teacher qualifications in the traditional school setting. Considering the fact that only minimal qualifications are required to be a teacher in China (Qian & Smyth, 2008), a lack of teacher quality is especially important in the Chinese educational context, as it implies positive teacher influence on student engagement is limited.

Teacher quality has become a challenge for the Chinese educational system and an obstacle to reform, mainly because of the constant focus on improving examination results (Dello-Iacovo, 2009). In fact, teachers often lack the skills needed to help engage their students in inquiry and class discussions (An et al., 2007), and are unmotivated to change their behavior to support student-centered teaching and learning (Dello-Iacovo, 2009). A study of Chinese teachers' adoption of more engaging instructional methods, such as leading an in-class discussion, found that teachers often engaged in the question-and-answer session, with the teachers pressuring the students to agree with them (Dello-Iacovo, 2009). When these teachers were asked to facilitate self-directed learning, they failed to provide students with adequate guidance or feedback (Dello-Iacovo, 2009; Li & Ni, 2011). Although self-directed learning requires students to initiate how to organize their learning (Abdul Jabbar & Felicia, 2015) and actively engage in social interaction (Carmean & Haefner, 2002; Wickersham & McGee, 2008), student initiation and active engagement were not observed in these research studies. The Chinese teachers in the research studies did not provide students with tools to understand the scope of their learning space, and were not adept at facilitating small group work, even though group work could promote social learning, active learning, and engaged learning (Dello-Iacovo, 2009; Li & Ni, 2011; Wickersham & McGee, 2008).

Recently, in 2021, the General Office of the Communist Party of China Central Committee and the State Council issued an official “double reduction” policy. As part of this education reform, schools and teachers in China are encouraged to improve the classroom teaching quality and use more creative teaching pedagogies to increase students’ creativity and competencies. This reform aims to reduce the impact of standardized examinations and improve education quality (Zhang & Chen, 2022). Researchers now endeavor to explore better teaching methods in the classroom to help students gain more independent study ability, improve metacognition to acknowledge how to deal with real-world problems, and make their learning experiences more relevant (Zhou & Long, 2022).

For example, some teachers are encouraged to use inquiry-based learning in the classroom. Inquiry-based learning is theoretically sound, but multiple barriers make it practically difficult for teachers to implement in the classroom. For example, under the pressure of high-stakes entrance exams, inquiry-based learning is not effective, as it is time-consuming compared with the lecture-recitation education associated with exam preparation, and does not immediately improve students’ scores (Dai et al., 2011). Limited understanding and skills of Chinese teachers in applying new teaching methodologies (Zhuang, 2009) is another barrier. A researcher of Chinese education observed, “there [has] been little change in classroom teaching with most teachers persisting with rote learning and memorization methods” even with new initiatives (Dello-Iacovo, 2009, p. 51). The practical difficulties experienced by Chinese teachers shows how important it is to consider the relevance of new instructional methods to student educational needs. These difficulties also provide a rationale as to why teachers in the Chinese school system have been ambivalent about educational reforms.

Private tutoring. The relatively low quality of teaching in schools leads students and families to turn to the private tutoring industry in China. This industry in China has been rapidly expanding in recent years (Zhang, 2014). Although the Chinese Ministry of Education prohibits school teachers from delivering home tutoring to their daytime students, these teachers privately tutor other students at night (Kwok, 2010). These tutors include active school teachers, retired school teachers, college students, and professional tutors who provide one-on-one tutoring after school through individual freelancing or as part of a chain of tutoring centers (Zhang, 2014). The number of students receiving private tutoring has steadily increased. For example, in 2001, 35% of Chinese students in grades seven through nine received tutoring services, but among seniors in high school, this number increased to 70% (Kwok, 2010). Interestingly, these numbers were much lower than the Chinese government's estimates, which put both numbers at 28% and 48%, respectively (Kwok, 2010). As the Ministry of Education does not typically release tutoring statistics, it is difficult to ascertain the patterns of tutoring usage in China (Kwok, 2010).

Tutoring subjects in China have been related to the daytime school curriculum. There is, however, a new trend in Hong Kong (a special administrative region of China) to use mass tutoring approaches, where tutoring services are multi-functional, providing homework guidance, lesson revision, and even food catering services on site in the school or nearby (Kwok, 2010). As the demand for tutoring in China is high, these mass tutorials are run by private businesses, and are virtually unregulated (Kwok, 2010). As such, although tutoring in China is a widespread phenomenon, it is still “hidden” in nature, because tutors can escape from monitoring, control, and regulation by tutoring out of their homes (Kwok, 2010). The Chinese government could not reasonably organize and exert professional control over this underground tutoring economy, and does not allocate effort to the excessive human power that would be necessary to do so (Kwok, 2010). Meanwhile, tutoring services remain relatively high-profile; the government has not prioritized regulating them, so although they continue to be accessible, they are officially “hidden” (Zhang, 2014).

The main reasons stated for hiring tutors include remediation and enrichment (Zhang, 2013), and highly-rated competencies for successful Chinese tutors include professional knowledge and skills, a sense of responsibility, fairness and justice, and care for students (Zhang, 2013). In contrast, the top reasons for not hiring a tutor include negative student perception of the tutoring effect, and high tutoring fee (Zhang, 2013). Chinese tutor competencies that were rated as not necessary for successful tutoring were evaluative feedback, attention to detail, a sense of principle, and a sense of art (Zhang, 2014). These preferences may reflect the historical focus on exam-based learning.

The cost of tutoring is prohibitive to many families. Household expenditures per student for tutoring were approximately 300 US dollars (USD) to 500 USD for low-income families, and 1,000 USD to 2,000 USD for high-income families per school year in 2010 (Kwok, 2010). While some urban families may be able to afford these prices, this is less likely in rural families (Brown & Park, 2002; Lu, 2012; Yi et al., 2012).

Nevertheless, the demand for tutoring is growing every day in China, and demand continues to outpace supply (Kwok, 2010).

It is not clear, however, how much of an advantage the private tutoring confers. On the one hand, researchers report that high-quality tutors in China do help students improve motivation (by way of their encouragement and enthusiasm), and increase engagement (by employing active learning approaches) (Zhou & Deneen, 2016). On the other hand, there are mixed effects of private tutoring on student scores on the college entrance examination in China (Zhang, 2013). These discrepancies imply that the quality of tutoring is not consistent throughout China and is lower quality in the rural areas, and some tutors may be more effective than others (Zhou & Deneen, 2016). Considering that tutors may not be as high quality in the rural areas, it is thus not clear whether rural students would see benefit from hiring a tutor (Zhou & Deneen, 2016).

The rural and urban education gap. Until the 2006 Amendment to the Compulsory Education Law in China, many rural schools charged tuition, which served as a barrier, preventing many rural students from reaching the stage to take the high-stakes examinations (Hannum et al., 2011). Even after the Amendment, the ever-widening urban-to-rural income gap continued to make it difficult for rural students to participate in college entrance examinations, thus dooming them to a life of poverty (Hannum et al., 2011; Sicular et al., 2007). The government shifted subsidies to fee-based upper secondary schools, and this represented another barrier to rural students attending college (Hannum et al., 2011). The proportion of rural students in national key universities has, thus, declined in recent years (Hannum et al., 2011).

Most research on inequity issues in China has centered around family income (Glazebrook & Song, 2013; Qian & Smyth, 2008). While it is generally agreed that recent widespread educational opportunities have positively contributed to economic growth in China, there is also the belief that the same opportunities have contributed to greater disparities in the socio-economic context (Qian & Smyth, 2008). For the Chinese education system to continuously drive the country's economic growth, and more importantly for the economic growth of China to be sustainable and equitable across regions, it is, thus, necessary to improve the education quality at every level (Glazebrook & Song, 2013). It is also critical for educational reforms to create a culture that recognizes and respects the skills, knowledge, and experience that Chinese people possess, and regards them as human capital (Glazebrook & Song, 2013).

Even though the Chinese government has pushed hard to achieve standardization and equality in education, the rural-urban gap in teaching quality has persisted (Brown & Park, 2002; Lu, 2012; Yi et al., 2012), and the rural-urban divide in educational attainment still is a severe concern for China (Qian & Smyth, 2008). Not only do rural areas have less-established educational infrastructures, but rural families face barriers to educating their children in terms of opportunity cost; this is because these families mainly engage in agriculture and need their children to assist on the family farm (Qian & Smyth, 2008). Naturally, there are high levels of drop-outs in rural China (Qian & Smyth, 2008; Yi et al., 2012). In 2001, only 52.6% of Chinese junior secondary graduates in the rural area were able to go on to senior secondary school (Brown & Park, 2002). As such, competition in primary school is extremely intense, and some children or families migrate to urban areas for educational reasons (Lu, 2012). Chinese children of age 15 and

16 who cannot attend senior secondary schools either become employees or remain unemployed, and will most likely spend the rest of their lives in China's lower classes (Dello-Iacovo, 2009).

Hannum and colleagues (2011) analyzed a survey of about 1,200 youth in 100 rural villages in Gansu Province, one of China's poorest interior provinces. When asked about high school entrance exam outcomes, 48% of the students reported not getting into a secondary school or not taking the high school entrance exam, or else they left the question blank. In the same study, 36% reported earning the lowest exam scores, and only 16% reported getting into a key school (Hannum et al., 2011). Another study found that 14.2% of rural students in China leave school by the first month of ninth grade (Yi et al., 2012). In contrast to these students, those who migrate out of the rural areas to the urban areas have been found to receive educational benefit, as they not only receive better education but also can get better jobs and send the family remaining in the rural areas remittances (Lu, 2012).

The barriers to completing school for rural Chinese students also are barriers to hiring a tutor. It is logical that fewer tutors would be available in the rural area because the drop-out rate is so high (Yi et al., 2012). It is, thus, likely that those who use tutors in rural areas are more likely to have their classroom teacher as a tutor (Zhang, 2013). In fact, professional tutors are more active in urban areas, likely because they are desired at high rates (Zhang, 2013). Students in rural areas are less likely to hire a professional tutor for Chinese, math, or English (Zhang, 2013).

The urban-rural gap is also reported in the adoption of the new textbooks promoted by New Curriculum reforms (Wang, 2011). While the new textbooks responded to the new standards of skills and capacities required for the new generation in both urban and rural areas of China, students from culturally- and economically-disadvantaged rural families have been overwhelmed by the textbooks due to their content difficulty as well as curriculum scheduling complexity (Wang, 2011). As the new textbooks contain requirements for more self-paced and student-centered lesson contents, which are contrary to the fixed-paced teacher-centered lesson contents, teachers have also not been adequately prepared for the new textbooks in part due to lack of support and training (Wang, 2011).

Rural schools in China also suffer from inadequate teaching quality, which is even worse than in urban schools. An empirical study reports that teachers in rural northwest China commonly adopt teaching styles that do not encourage student engagement in the classroom, and this may have impacted educational attainment of students (An et al., 2007). Another empirical study reports that students in lower quality teaching schools in rural China are more likely to drop out (Brown & Park, 2002). A study comparing rural and urban teachers in China documents that even with similar teaching methods, urban teachers ask more challenging questions to students and provide more variety of activities in classrooms (Chan & Rao, 2010).

Children in the rural area left behind. Along with market and economy transitions, China experienced enhanced internal migration of labor from the rural area to the urban area, which was initiated in 1978, and has resulted in between 150 and 180 million rural to urban migrants in the recent decade (Chang et al., 2011). This trend has caused children who are left behind in the rural home to spend more time with other members of the family, such as the elderly, or women who live with remittances (Chang et al., 2011). Research by Lu (2012) has revealed positive economic development in families with migrant parents; in those families, children seem to exhibit increased satisfaction with their living conditions due to improved economic resources. This improved financial status, however, fails to correlate with school performance. Instead, lacking parent-child interaction and communication leads to emotional and behavioral problems for left-behind children, and plays a pivotal role in their academic performance (Lu, 2012). Left-behind children are more disadvantaged in terms of health behaviors and school engagement when compared with those living in non-migration families (Wen & Lin, 2012). The left-behind children population reached 58 million in 2012 (Lu, 2012). As these children have formed a unique youth population in China, they deserve serious attention in terms of community-building and being a target of research (Wen & Lin, 2012).

Educational Opportunity in China

Online learning. Over the recent decades, the development of online learning in China has made considerable progress and achievements in both formal and informal education, such as schools, businesses, governments, and community organizations (Wang, Liu, & Zhang, 2018). Online learning provides unbeatable opportunities, not only for the construction of infrastructure and learning resources, but also for market growth, as well as academic and non-academic education and training. In particular, online learning brings a tremendous opportunity for disadvantaged groups, such as those living in the rural areas and remote mountain areas of China. For example, since 2003, the Chinese government launched a rural elementary and secondary school distance education project, which aims to provide rural area students with quality learning resources via various formats of technology (Wang et al., 2018).

The expanded internet infrastructure in rural China has also opened up possibilities for online education as well as other types of support, such as building an "online commune" for farmers in the rural area (L. Huang et al., 2015). Individuals in the rural area can use the online commune communication platform to facilitate farm work, obtain medical care, and improve connections with governmental officials and agencies (L. Huang et al., 2015). There are already over 20,000 broadcast stations, over 48,000 satellite reception stations, and over 7,000 computerized classrooms have been built in 12 provinces in West China, and up to 6.44 million rural students benefit from this online learning expansion (Wang et al., 2018).

Internet connectivity continues to increase in rural areas. In 2014, 180 million rural residents of China had access to the internet, and this was expected to increase to 250 million by 2018 (iResearch Consulting Group, 2018). In April 2018, the Chinese government started a new initiative called the Rural Area Teacher Support Plan, which was a five-year plan to develop an online platform to support teachers technologically and help rural students achieve educational equity (iResearch Consulting Group, 2018). Massive Open Online Courses (MOOCs) are also becoming widespread in China and may be able to connect rural area students with more educational options (Luo & Zheng, 2015).

Gaokao – The National College Entrance Exam (NCEE). Adopted in 1952, Gaokao (高考; gāokǎo), which is called the National College Entrance Exam (NCEE) in English, is considered as the world's first standardized examination, and takes place only once a year on the same date at same time in the whole nation of China (Muthanna & Sang, 2015). Gaokao is a high-stakes test for which almost every Chinese student studies throughout their twelve-year compulsory education. Because getting a higher score on Gaokao is critical to entering a more reputable college and consequently improving chances for a future career and networking, Gaokao is a decision-maker in a student's life (Muthanna & Sang, 2015).

Many researchers have criticized Gaokao for its limited flexibility and its inability to measure soft skills, such as emotional intelligence and communication (Muthanna & Sang, 2015). Because of the singular focus on Gaokao throughout Chinese education, students lack social development, and do not gain people skills to the level needed to interact in the workplace or be successful in relationships (Muthanna & Sang, 2015). This is a problem throughout the system, as it incentivizes ignoring cultivating these skills in children as part of education (Muthanna & Sang, 2015). Most researchers call for reform of Gaokao, contending that it should focus on skills needed for a student's professional development, and should comprehensively assess the student's learning performance throughout the whole learning process in order to foster the student's learning autonomy, critical thinking skills, creative ability, and social-emotional growth (Li & Long, 2008).

As with Gaokao, other examinations in the Chinese education system play a critical role, because they determine a student's learning path and their level of schooling. For example, the high school entrance examination determines whether the student transitions to secondary school or vocational school, and the college entrance examination determines the tier of college to which they transition. Unfortunately, the literature reveals that low-income families are vulnerable in the examination system, even beyond the income gap (Hannum et al., 2011).

The recent expansion of higher education in China, nonetheless, offers opportunities for socio-economically disadvantaged students to enter college and change their current life situation (Wang, 2011). While the resource gap between urban and rural education cannot be ignored or easily overcome, focusing on improving the quality of education in the rural area presents an opportunity to improve the fairness behind the Gaokao and education system in China.

Fairness of the Chinese education system. The overall enrollment growth in higher education indicates that fairness in the Chinese education system is increasing. The government is making further efforts to make more progress to close the educational gap between urban and rural areas (Wang, 2011). An education satisfaction survey conducted in 2005 showed that the majority of the public were dissatisfied with the fairness of the current education system and reforms due to the gap between the urban and rural areas, and also, due to the fact that more urban students could access better-quality education resources and have more opportunity to enter key universities (Dongping, 2006).

Despite these setbacks, there are still opportunities for educational reform to achieve fairness in China. For instance, technology and the internet can be used to close the gap between urban and rural education quality by delivering quality training for teachers, and offering contextually-appropriate contents to rural and remote mountain-area students (An et al., 2007). Providing support for families in need, such as the left-behind children in the rural areas and children of labor migrants, can help close the gap between urban and rural education as well (Wen & Lin, 2012). Recognizing different factors that affect education fairness, such as the father's education level, the family income level, and the social class dimension, could also help reduce the disparity in education quality between urban and rural areas (Dongping, 2006).

Deeper Learning

Deeper learning is defined as "the process of preparing and empowering students to master essential academic content, think critically and solve complex problems, work collaboratively, communicate effectively, have an academic mindset, and be self-directed in their education" (Martinez & McGrath, 2014, p. 4). Deeper learning, accordingly, aims to enable learners to have the ability to apply learned knowledge to real-world circumstances and to solve novel problems (Martinez & McGrath, 2014) by engaging learners to actively explore, reflect, and even produce knowledge (Wickersham & McGee, 2008).

Wagner's Definition

According to Wagner (2008), although deeper learning focuses on solving real-world problems, globally, education has been focusing on academic scores and performance, and does not prepare students for modern-day careers and citizenship. Fortunately, more and more teachers, institutions, and parents are noticing that different skills are needed to succeed in the current climate, and academic performance is only one factor. There are many skills that today's students need, such as being able to solve open-ended problems, engage in ongoing learning to adapt to the rapidly changing job market, and collaborate with diverse people from the global and international workplace (Mehta & Fine, 2015). American schooling is refocusing its values to meet societal demands of reforming educational policy, improving the quality of teaching, and doing a better job of preparing students for college and lifelong learning (Hirsh-Pasek et al., 2020).

Global education reform is shifting to deeper learning principles to help students adopt the critical skills leaders expect them to have in the workplace (Wagner, 2008). First, leaders expect their employees to have critical thinking and problem-solving skills, which includes the ability to ask the right questions, improve their productivity, and solve new problems that they may encounter every day at work. Second, leaders want individuals who can collaborate and take the leadership role. Thanks to the advancement of technology, the top-down accountability structure is increasingly being replaced. As such, teamwork and collaboration skills are necessary to manage work across networks, rather than work with just a few nearby coworkers. Collaboration and leadership skills also relate to the ability to influence others rather than direct and command them.

Third, as business is constantly evolving, employers seek individuals who have adaptability and learning skills, rather than solely technical skills. Fourth, organizations search for individuals who are creative and willing to set stretch goals. Organizations avoid individuals with the reluctance to change because this is detrimental to growth. Hence, a culture of initiative and entrepreneurialism is recognized as necessary (Wagner, 2008).

Fifth, leaders want individuals who can communicate effectively. To be effective communicators, individuals should have the ability to be clear and concise in verbal, written, and presentation skills. They also should be able to express themselves with focus, energy, and passion. Sixth, employers seek individuals who can process information effectively. In the current age of data, where a vast amount of information is constantly created and disseminated, it is ever more important to filter and digest information effectively to be efficient. Finally, industries require individuals who have the capacity for imagination, creativity, and empathy (Wagner, 2008). As business is competitive, individuals lacking these qualities will not have an advantage in business.

Common Core Standards and Next Generation Assessments

In terms of Chinese education reform, the benchmark examination is one of the critical opportunities for Chinese rural students to receive more educational support. The Chinese government is expending effort to balance promoting effective standards examinations along with developing well-rounded students from the delivery of quality education. The approach to deeper learning and assessment in the US could offer a meaningful framework for China.

Deeper learning must focus on imparting twenty-first century skills so that students can meet international benchmarks for college- and career-ready standards in literacy and numeracy (VanderArk & Schneider, 2012). In the US, these benchmarks could be seen as equivalent to the Common Core standards. Common Core standards were a set of goals for knowledge for students to achieve at each grade that were rolled out to states in 2010 (Litkowski et al., 2020). The Common Core standards have defined criteria for readiness to college or workplace training programs (Rothman, 2012); hence, the Common Core standards have been explicitly designed around the goal of preparing students for college and career readiness. Much research has been conducted on how to meet this goal for all students (Litkowski et al., 2020).

In 2013, the National Conference of State Legislatures declared an initiative titled Next Generation Assessments (Heintz, 2013). The reason this initiative was put forth was that it was found that assessments for students' achievement of the Common Core standards was not fair to certain classes of students, such as those with disabilities. Therefore, teachers were encouraged to develop more enlightened methods to conduct assessments, which is the concept behind Next Generation Assessments. States formed consortia and developed more flexible assessment approaches, such as the Smarter Balanced assessment system, which is has optional components and can be used locally (Heintz, 2013). Next Generation Assessments are improved in many ways, including that they do a better assessment of critical thinking, which is an important skill to acquire in order to be career-ready (O.Liu et al., 2014).

Hewlett Foundation Framework

Along with government agencies, foundations have also put efforts to promote deeper learning. For example, the William and Flora Hewlett Foundation developed a framework to help kindergarten through twelfth grade schools in the US to "shift course" to adapt to the rapidly changing society and get students ready to engage in their work and civic life after graduation (Farrington, 2013). Their framework consists of six competencies that are measurable, teachable, and evidence-based. The first competency is to master core academic content. To demonstrate this competency, learners should be able to understand key principles and relationships within a content area, be able to remember the facts within the content area and apply them to various academic subjects, and not only retain procedural knowledge but be able to produce knowledge and solve problems (Farrington, 2013). The second competency is critical thinking and complex problem solving. To demonstrate this competency, learners should be able to formulate problems and generate hypotheses, apply tools and techniques to gather data and information, integrate this information into arguments and reasoning, and persist until they solve such a complex problem (Farrington, 2013).

The third competency in the Hewlett Foundation framework is working collaboratively. To demonstrate this competency, learners participate in a team to plan problem-solving steps, collaborate with others to complete tasks and identify group goals, and communicate and integrate multiple points of view in accomplishing group assignments (Farrington, 2013). The fourth competency is communicating effectively. To demonstrate this competency, learners should be able to communicate complex concepts in both written and oral form, structure data and information in meaningful ways, receive and give constructive feedback, and understand how to use multiple revisions, reviews, and drafts to create quality communication (Farrington, 2013).

The fifth competency of the Hewlett Foundation framework is learning how to learn. This is an extensive competency with many facets, including having learners be able to demonstrate self-direction through goal-setting, monitoring their own comprehension and navigating through obstacles, reflecting on learning experiences and becoming aware of strengths and weaknesses, and working towards lifelong learning (Farrington, 2013). Finally, the sixth competency is developing an academic mindset. This entails the learner feeling as if they belong to an academic community, that they can succeed in an academic setting, that their ability and competence grows parallel to their effort, and that the work of learning has value to them (Farrington, 2013). These competencies for deeper learning are consistent with related empirical evidence that supports that deeper learning students are doing better than their peers in terms of graduation rate, college enrollment, interpersonal and interpersonal skills, and test scores

(Yang et al., 2016). Hewlett framework provided the foundation of how deeper learning contributes to students' different capabilities dimensions.

Carmean and Haefner Framework

Others have developed different deeper learning frameworks. Carmean and Haefner (2002) reviewed the literature and summarized five deeper learning principles: social, active, contextual, engaging, and student-owned. By social, they were referring to learning that includes reciprocity and cooperation among students, prompt feedback, and interaction between students and faculty (Carmean & Haefner, 2002). By active, they meant learning that is engaged in solving real-world problems, that involves using judgment, exploration, practice, and reinforcement. For contextual, the authors described learning that is built upon the learner's existing knowledge, includes the awareness of preconceptions and factual knowledge, and cultivates the ability to operate within the context of a conceptual framework (Carmean & Haefner, 2002). By engaging, the authors were referring to learning that respects diverse talents and ways of learning, emphasizes intrinsic motivators and natural curiosity, and is done in a high-challenge, low-threat environment (Carmean & Haefner, 2002). Finally, by student-owned, the authors were referring to learning that emphasizes learner independence and choice, provides the learner space and time for reflection, allows learners to organize knowledge in a way that facilitates their retrieval and application of it, and encourages learners to take control of their own learning (Carmean & Haefner, 2002).

All the frameworks provided the comprehensive understanding of the context and concepts of deeper learning and its outcomes. However, these frameworks lack clear criteria or measurement of deeper learning and its outcomes.

Wickersham and McGee's Framework

The most arguably robust framework used for developing curricula with deeper learning principles is the one put forth in an article by Wickersham and McGee (2008). With a special focus on incorporating what they call deeper learning principles (DLPs) into online learning, they identify nine DLPs (described in Table 1).

Table 1

Deeper Learning Principles from Wickersham and McGee (2008)

Principle	Examples
1. Active Learning	Solving real-world problems. Inquiring about new ideas. Analyzing new ideas. Producing an item through a learning activity Collaborating in a learning activity.
2. Social Learning	Learning through interaction with peers. Receiving immediate feedback. Receiving authentic assessments.
3. Learner Context	Being able to choose what to learn. Being able to choose from different learning models. Being able to engage in higher order evaluation Being able to choose activities build on existing skills and knowledge
4. Engaged Learner	Being able to choose how to learn. Choosing specific goals or objectives for learning. Having access to multimodal information sources.
5. Learner Ownership	Being able to set goals and timelines. Being able to choose the format of end-products. Having the ability to document reflection. Having the learner identify problems, processes and solutions.
6. Technology-supported	Being able to learn in any physical setting chosen. Being able to choose from multimodal technological information sources. Having access to both public and private online functions. Being able to interact through a deep rather than surface interface.

Table 1 (continued)

Principle	Examples
7. Intuitive Design	Having intuitive navigation and usability Having multi-modal content options Having clear criteria for performance and completion Accessible to those with disabilities
8. Engaged Activities	Being able to contribute products and assignments in public. Being able to collaborate and cooperate on learning activities. Having the ability to apply, synthesize, and evaluate learned knowledge.
9. Facilitative Teaching Practices	Being able to determine learning objectives. Being responsive to learner to accommodate the learner. Having the learner engage in activities of purposeful knowledge negotiation and acquisition.

Note. Adapted from Wickersham and McGee (2008).

As noted in Table 1, the nine DLPs are consistent with the five deeper learning principles put forth in Carmean and Haefner's (2002) framework, as well as the competencies in the Hewlett Foundation framework (Farrington, 2013). While the Hewlett Foundation framework and the Common Core standards are relevant specifically to the US, the framework from Wickersham and McGee is generically applicable to all countries and contexts. Further, the Wickersham and McGee DLPs framework represents the culmination of rigorous research in the peer-reviewed literature, not a report from an educational foundation. This makes the Wickersham and McGee framework be at a higher quality of evidence.

Factors Influencing Deeper Learning

Learner's Intention. To benefit from deeper learning curricula, learners need to have the intention of understanding the learning content, instead of intending to merely memorize the content without understanding it, as is currently happening currently in China (Dello-Iacovo, 2009). If learners have deeper learning intentions, teaching strategies promoting comprehension may displace the ones currently used for rote-learning (Qian & Smyth, 2008). The importance of learning intention for deeper learning is documented in the literature. For example, in their research on Hong Kong students' learning approaches, Lo and Hyland (2007) stated that using a deeper learning teaching strategy would not be successful if the students do not have the intention to understand the material, and only want to memorize it (as per the stereotype). Hattie and Donoghue (2016) also argue that if the learner's intention is surface learning, then deeper learning would not occur.

Student Motivation. Student motivation is associated with consistent engagement in deeper learning activities (Farrington, 2013), and learners who set long-term goals are more likely to be motivated toward deeper learning strategies (Dweck et al., 2014; Ryan & Deci, 2017). Hattie and Donoghue (2016) argue that intrinsic motivation, defined as motivation for internal education-related goals (such as feeling interested in the course), is necessary for the learner to move past surface learning into deeper learning. While generally sharing this view, Kember (2000) also highlighted the role of extrinsic motivation, defined as motivation toward external goals (such as having a good career) on curriculum-based learning. In his study of students in Hong Kong, Kember (2000) showed high levels of motivation were exhibited that were collective in nature, rather than being individual and competitive. This finding of collective motivation is similar to the finding from a study by Herrmann (2013), which showed that cooperative learning increased in-class participation, suggesting that having collective motivation in a group can be a feature leveraged by the educator to increase engagement.

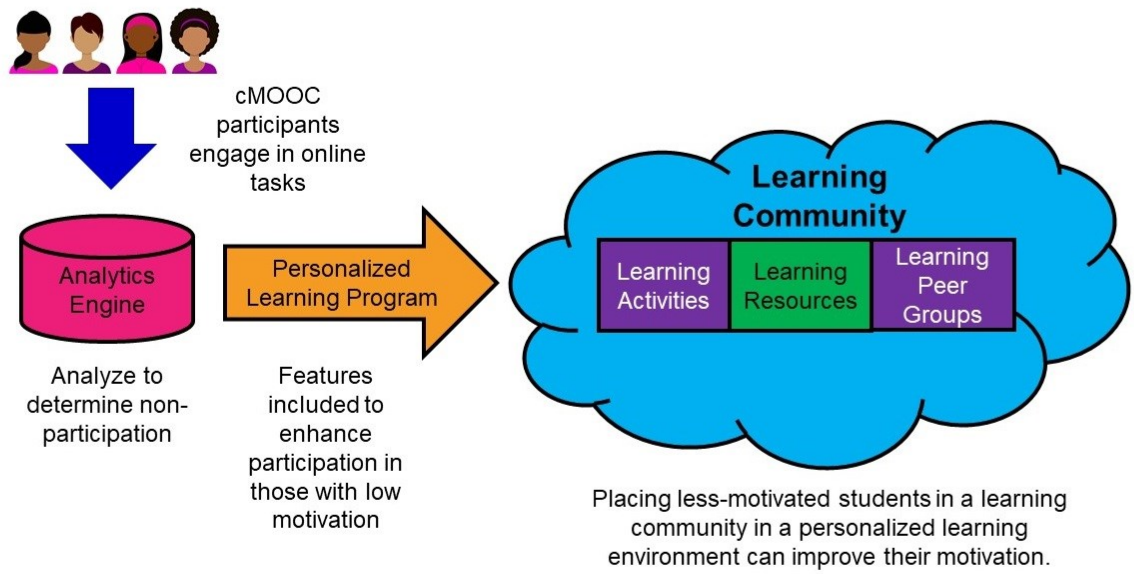
Student Engagement. Engagement is a critical component of deeper learning, and closely related to motivation. In their study on patterns of engagement and factors mediating student engagement within a connectivist massive open online course (cMOOC), Milligan and colleagues (2013) suggest three types of participants: active participants, passive participants, and lurkers. The active participants in the cMOOC are those who maintain active blogs and Twitter accounts, and regularly participate in the class discussion, exhibiting a high motivation to persist with the course. Passive participants often drop out early during the process of learning due to lack of motivation to persist. Passive participants also show frustration and dissatisfaction with the course, likely representing those who do not like online courses or who are averse to technology (Milligan et al., 2013).

The third group, lurkers, actively read and observe the interactions of the active participants, but do not interact with other learners. Nonetheless, lurkers were satisfied with the course, likely representing people who are engaged but not interested in participating in the social aspect of the engagement (Milligan et al., 2013). These findings collectively suggest that social learning needs may differ among individuals. As such, adaptively generating personalized learning is suggested to increase engagement in cMOOCs (Blanco et al., 2013).

Figure 3 summarizes how a cMOOC can improve learner motivation through adaptivity.

Figure 3

cMOOC Adaptivity to Inspire Demotivated Participants. Adapted from Blanco et al. (2013)



As shown in Figure 3, adaptive cMOOCs can use analytics from participation to generate personalized learning for each participant based on their profiles, interests, learning experiences. During the learning process, cMOOCs can present the learner with personalized activities and resources, and place the learner in groups with peers to form a learning community to enrich interactions and cooperation among participants (Blanco et al., 2013). As adaptive cMOOCs respond to an individual's learning needs, they can help address the issues that commonly occur in cMOOCs due to declining participant motivation, such as high drop-out rates and insufficient participation in cooperative activities (Blanco et al., 2013).

The relationship between student engagement and knowledge gain has been supported by educational game studies. For example, in a mixed-methods study of a multi-player educational game called *Dr. Friction*, students who engaged the most in the game gained the most knowledge, regardless of gender (Annetta et al., 2009). Findings from another study focused on *Farmtasia*, a roleplaying game about making agricultural and financial choices, are consistent with the ones from the study of *Dr. Friction* (Jong, 2015). The competitive nature of *Farmtasia* attracted student engagement and increased student knowledge of the lesson (Jong, 2015). But it is worth noting that learners must be motivated to play the game in the gamified curriculum in order to be engaged (Abdul Jabbar & Felicia, 2015).

While competitive gameplay in a gamified curriculum can increase student engagement, this does not necessarily foster deeper learning (Abdul Jabbar & Felicia, 2015). Simulation gamification of curricula that are both more engaging and applicable to the real world may represent an alternative that more appropriately leverages deeper learning principles (Grover et al., 2015; Henning et al., 2014). Providing challenging and complex simulation gamification with real-world features could not only promote the learner applying theoretical knowledge in a real-world context, but would also allow the learner to gain skills in dealing with ambiguity and vagueness in real-world situations (Connolly & Stanfield, 2006). Simulation gamification also can facilitate the development of problem-solving skills in learners which are transferable to real-world situations (Connolly & Stanfield, 2006). For the online simulation gamification to be more amenable to deeper learning, it should also improve the learner context and increase learner ownership (Wickersham & McGee, 2008). Consequently, online real-world simulations can increase student confidence and motivation, while also giving them time to reflect upon their practice, and develop metacognitive strategies so they can adapt to new situations (Connolly & Stanfield, 2006).

The role of uncertainty needs to be well considered when gamifying educational experiences, as the uncertainty embedded in a gamified educational setting is negatively associated with motivation, influencing student engagement (Howard-Jones & Demetriou, 2009). For example, in a study of students aged ten and eleven playing a gamified math quiz, before being shown each math question, participants were asked to choose an option of receiving either a reward of a single point with certainty, or a number of points ranging from zero to two based on the flip of a coin (Howard-Jones & Demetriou, 2009). A preference for the option to toss the coin increased as the quiz progressed (Howard-Jones & Demetriou, 2009). Another study involving adults that was reported in the same paper also showed that participants were more motivated when their success depended somewhat (but not fully) on the result from rolling of a pair dice (Howard-Jones & Demetriou, 2009).

Learner-Engaged Assessment. Learner-engaged assessment (also called student-engaged assessment) is a factor that plays an important role in deeper learning. Learner-engaged assessment is a system of assessment involving learners to monitor their own learning (Berger et al., 2014). Its focus is on motivating learners to learn, not on evaluating and ranking learners (Berger et al., 2014). The idea behind learner-engaged assessment is that learners can gain from being engaged in the assessment of self and others in a class by learning how to evaluate work and provide feedback (Berger et al., 2014). This type of engagement is more straightforward to facilitate in the face-to-face classroom than online because learners are in the same location as the teacher. The teacher can help learners to assess each other as a class exercise. In an online learning environment where learners and teachers are not in close proximity, teachers still can facilitate learner-engaged assessment by promoting the use of online tools such as an online rubric. In one study, learners who used an online rubric for self-assessment exhibited improved learning performance and used more of the learning strategies compared to a control group that did not use the rubric (Panadero & Romero, 2014).

Learner Attitude. Learner attitude plays a role in deeper learning. Results from one study showed that students who have a negative perception of online learning are less likely to benefit from it (Kauffman, 2015). In another study of a gamified curriculum, students who were not interested in computer usage did not benefit from using the curriculum (Jong, 2015). Thus, in developing curricula for deeper learning, it is important to consider the learners' attitudes. If learners have a negative attitude toward online courses or a gamified curriculum, then it will be difficult to promote deeper learning.

One may argue that it is still possible to facilitate deeper learning for students with negative attitudes toward online learning. For this to occur, however, it is critical to have an optimal instructional design. One study that examined three different instructional designs showed that learners were significantly more satisfied with the content that is unstructured and adaptable (defined as "integrated" in the study) than that which was moderately structured (defined as "wrap-around" in the study) (Kauffman, 2015). This finding suggests that the least amount of structure to a course may offer the most satisfaction for the learner (Kauffman, 2015).

Metacognition. Metacognition is defined as the ability for one to reason about one's own cognitive processes, and to adjust and manage one's own behavioral and environmental functioning according to the demands one faces (Veenman, 2017). Originally defined in a 1976 paper by Flavell, the concept of metacognition continues to play an important role in deeper learning (Sheikh et al., 2019). For deeper learning to occur, metacognitive processes facilitating knowledge construction must be leveraged and stimulated (Aleven & Koedinger, 2002). Metacognition is necessary for students to get meeting out of their learning experiences from a deeper learning curriculum (Stover & Seemiller, 2017).

Metacognition is also known as a higher level of knowledge that requires more executive function in order to coordinate learning behaviors (Schultz, 2012), a skill that is preferred by employers from a variety of industries. Boyer and colleagues (2006) found in their study of graduate students that they felt more successful and confident within an interactive and cooperative learning environment, where the individuality of each student was emphasized, and an individual's own metacognitive awareness was fostered. Huffaker and Calvert (2003) argue that metacognition and deliberate strategies play a critical role in learner engagement in terms of deep processing. Engaged learners must do planning in terms of setting learning goals, monitoring themselves by keeping track of their progress on tasks, and maintaining control of the learning process through their management and use of learning strategies (Dori, 2017). Engaged learners also reflect upon their learning process, so deeper learning strategies make metacognitive skills imperative (Dori, 2017).

Role of Teachers in Deeper Learning. Teachers play a critical role, even in a learner-centered setting or an environment that emphasizes learner autonomy. As such, teachers must understand what deeper learning entails. To help teachers, Martinez and

McGrath (2014) identified six strategies and pedagogical practices that were demonstrated to improve deeper learning outcomes. First, they recommend empowering students in a traditional setting as independent learners. Next, they encourage teachers to contextualize knowledge so that it is coherent for the learner (Martinez & McGrath, 2014).

Third, according to Martinez and McGrath (2014), teachers should connect their curricula with real-world experiences of their learning audience. Fourth, teachers should encourage learning beyond the educational setting, and fifth, teachers should inspire learners through the customization of learning experiences. Finally, teachers should work to purposefully incorporate technology to enhance learning, but not automate it (Martinez & McGrath, 2014). Ultimately, being able to develop and deliver a deeper learning curriculum requires enhanced skills on the part of the teacher (Wickersham & McGee, 2008).

Measurement of Deeper Learning. Although deeper learning strategies and pedagogical practices may improve the quality of teaching, measuring the effectiveness of applying deeper learning principles in teaching is difficult because of the diverse topics, types of learners, and learning environments used to promote deeper learning. The existence of multiple lists of deeper learning principles also makes this measurement difficult (Carmean & Haefner, 2002; Crawford & Schmidt, 2004; Wickersham & McGee, 2008). As described earlier, while Carmean and Haeffner (2002) offer a list of deeper learning principles containing five principles, Wickersham and McGee (2008) offer a list of nine principles. As such, it is hard to tell whether a particular curriculum promotes a certain deeper learning principle.

Reflecting this complexity, various reports regarding the incorporation of deeper learning principles into curricula have shown mixed findings (Colasante & Lang, 2012; Grover et al., 2015; Lloyd, 2014). Overall, to achieve deeper learning in a course, the challenge lies in expert instructional design that successfully targets diverse levels and types of learning. As an example, for conceptual learning to better promote deeper learning, it will need to be paired with the learning of facts, or factual learning (Kauffman, 2015). In online learning, it is also advised to include metacognitive learning, as students will need to develop their own strategies for using the curriculum, such as planning, staying organized, and staying motivated (Kauffman, 2015). When the continuous effort is made to transform the online learning environment into more learner-centered and to foster autonomy and metacognitive awareness, deeper learning will become more likely to occur (Dole et al., 2015; Majeski et al., 2016). Designing a deeper learning curriculum around a best practices framework focusing on the most evidence-based deeper learning principles is also recommended (Wickersham & McGee, 2008).

Best Practices in Deeper Learning. Wickersham and McGee (2008) provide specific guidance in developing learning designs that support deeper learning. In their study, the authors analyzed data from the Distance Education Learning Environments Survey (DELES), which is a survey of online learning students from 13 countries, who are primarily from the US, Australia, New Zealand, and Canada (Wickersham & McGee, 2008). Their analysis revealed nine features of the ideal deeper learning environment (described earlier in Table 1). These features of the deeper learning can be universally applied, as they identify deeper learning features that can be implemented digitally and globally, such as posing compelling questions, and engaging in cross-cultural inquiry (Spires, 2016).

Fostering deeper learning is not an easy task. It is particularly challenging in an online environment, as the methods of delivering the curriculum required for deeper learning affects the interface of the chosen course management system (CMS) and necessitates diverse online means to be able to make the CMS content look, act, and operate appropriately (Wickersham & McGee, 2008). For example, as social feedback and interaction between learners and an instructor are critical for successful deeper learning, an online social interaction mechanism would need to be supported (i.e., social learning principle) (Wickersham & McGee, 2008). The CMS should also facilitate receiving real-time responses to the learners' experience of learning, as well as a way for learners to use online video lectures and resources (Lloyd, 2014). The CMS would also need to support individualized learning, which responds to the learner's unique needs so that the learner can be more motivated and appropriately challenged, as learner engagement is important for deeper learning to occur (i.e., engaged learner principle) (Wickersham & McGee, 2008).

The individualized learning further cultivates ownership of the learners in their learning experience (i.e., learner ownership principle) (Wickersham & McGee, 2008). Therefore, the curriculum and instructional design for deeper learning in an online environment must be not only well-conceptualized but also adaptable and flexible, so the learner can customize their unique learning context (Wickersham & McGee, 2008). Different learners have different needs; adolescent immigrants and English language learners would have different deeper learning needs than fluent English speakers, so the curriculum must be able to adapt to its audience (Gandara, 2015).

Solving real-world problems in an environment allows the learner to practice and receive reinforcement of their learning (i.e., active learning principle) (Wickersham & McGee, 2008). Images, language, scenarios, and any other devices can be used to improve the realism of the experience; these should both look real and feel real, and should be presented so the learner can interact with them (Wickersham & McGee, 2008). Making the learning contextual (or in the context of the learner) is quite different from the typical Chinese curricula, where the learner proceeds through the content in a pre-specified order with little or no adaptation, and no deviation from a content-driven script (i.e., learner context principle) (Wickersham & McGee, 2008).

Wickersham and McGee (2008) found that for online learning platforms to support deeper learning, they need to be technology-supported, have an intuitive design, and present activities that engage the learner. An example of this type of deeper learning platform was demonstrated in a study of the use of a media annotation tool (MAT) to enhance engagement with learning materials (Colasante & Lang, 2012). The authors also determined that there is a need for facilitative teaching practices that are objective-driven and respond to the learner (Wickersham & McGee, 2008). One study of a cyber-classroom implementation emphasized facilitative teaching practices to foster deeper learning, showing that this is possible even in a digital environment (Goldman, 2008).

Educational Technology

Educational technologies can empower teachers to achieve instructional strategies such as case-based learning, collaborative learning, self-directed learning, interdisciplinary studies, personalized learning, connected learning, and formative assessment (Dede, 2014). Educational technologies can also help students access more learning resources, learn from peers, experience personalized learning, and be prepared for innovative learning to succeed in novel working environments (VanderArk & Schneider, 2012). In addition, educational technologies, especially adaptive learning and microlearning technologies, have the potential to promote deeper learning and strengthen students' learning experiences (VanderArk & Schneider, 2012).

The positive role of educational technologies is appreciated at the time of unexpected educational disturbances such as natural disasters or pandemics. For example, the unprecedented COVID-19 pandemic, which hit 219 countries globally during 2020 and 2021 and caused school closures, created an opportunity for educational technology to become an essential way to help schools and teachers to maintain learning for students (Chick et al., 2020). As the first COVID-19 case occurred in China, China launched a project called, "Suspending classes without stopping learning" across the whole nation as the first educational policy response to this novel virus (Zhang et al., 2020). With the wide use of the video communication software "DingTalk" (equivalent to "Zoom", widely used in the US (Huang et al., 2020)) and diverse educational technologies, large-scale online education was launched which benefited both Chinese teachers and students during the COVID-19 pandemic. This educational shift also significantly increased opportunities to investigate how teachers and students learn online, and methods to launch and assess online education and educational technologies (Zhou et al., 2020).

Adaptive Learning. The idea of individual differences in learning is widely accepted. Students exhibit different learning needs, interests, goals, behaviors, and outcomes. While a venerable ideal, accommodating each student's different learning needs is a challenge that all educators and educational institutions face. Adaptive learning technology can offer help for teachers to overcome this challenge by allowing them to collect and analyze student learning data and consequently adjust instructional contents to make sure they achieve outcomes for benchmark learning assessment (Aleven et al., 2016).

Adaptivity. In the context of the learning environment, the term "adaptivity" can be defined in three different perspectives: design, pedagogical decision-making, and interactivity (Aleven et al., 2016). Adaptive learning aims to set challenges and objectives for learners (design), adjust pedagogical context based on learners' progress and change through the learning experiences (pedagogical decision-making), and interactively respond to learners' actions, which may include their indications of their progress and degree of mastery of knowledge (interactivity) (Aleven et al., 2016). Paramythis and Loidl-Reisinger (2004) share similar ideas about adaptive learning:

> *A learning environment is considered adaptive if it is capable of: monitoring the activities of its users; interpreting these on the basis of domain-specific models; inferring user requirements and preferences out of the interpreted activities, appropriately representing these in associated models; and, finally, acting upon the available knowledge on its users and the subject matter at hand, to dynamically facilitate the learning process. (p. 182)*

Reviewing adaptive and intelligent technologies for web-based education, Brusilovsky (1999) reports similar core concepts and supporting technologies involved in such systems. They include curriculum sequencing, which refers to sequencing activities towards a learning goal, and intelligent analysis of student's solutions, such as providing individualized feedback and updating the student model. Another core concept is interactive problem-solving support, such as offering help and updating the student model. Paramythis and Loidl-Reisinger (2004) suggest similar adaptive characteristics that learning environments need to support learning: adaptive interaction, adaptive course delivery, content discovery and assembly, and adaptive collaboration (Paramythis & Loidl-Reisinger, 2004). Adaptive interaction addresses the system interface to facilitate learners' interaction with the learning environment. Adaptive course delivery concerns customizing learning resources and course structure to meet the students' learning needs, thus achieving optimal learning outcomes. Content discovery and assembly refers to assembling different learning content based on learners' needs and data collected from their experiences. Finally, adaptive collaboration support addresses supporting social collaboration, interaction, and communication to facilitate the learning process, which is very important for the modern online learning environment.

Background. Efforts to offer individualized instruction to help students achieve optimal learning outcomes have existed for decades since Bloom proposed Learning for Mastery (LFM) (Bloom, 1968) and Keller proposed Personalized System of Instruction (Keller, 1968). These two main pathways to mastery learning promote different strategies to provide students with individualized content to master the knowledge. LFM, for example, is teacher-centered. Teachers are in charge of the speed of learning, and if a student fails to pass the unit formative assessment, a tutor helps the student improve their understanding of learning contents. Contrary to LTM, PSI is student-centered. Students engage in self-paced learning, and have to restudy the learning resources if they fail a unit formative assessment (Kulik et al., 1990).

While their strategies differ, both systems offer short, unit-sized lessons that students may learn in small chunks. Students then take a formative assessment at the end of each unit in order to proceed to the next. While they are both effective, due to both LFM and PSI being effort-intensive and having high resource-demand, obstacles are initially encountered when implemented on a larger scale. With the advancement of increasingly sophisticated technologies such as artificial intelligence (AI) and machine learning (ML), the implementation of individualized, adaptive learning has become more realistic (Kulik & Fletcher, 2016).

Empirical Evidence. Intelligent tutoring systems (ITSs) could be described as computer-supported learning environments offering personalized learning support using artificial intelligence. These are among the earliest and most investigated adaptive learning technologies. Documentation of the ITSs' potential as an efficient adaptive learning technology goes back to almost three decades ago (Psotka et al., 1988). Since then, the potential of ITSs has significantly increased with the advancement of artificial intelligence technology and big data availability (Koedinger et al., 2013).

ITSs have been investigated in multiple educational domains. According to Xie et al.'s (2019) systematic review of publications regarding technology-enhanced adaptive learning from 2007-2017, most of the studies adopted science, technology, engineering and math (STEM) topics and language topics as learning contents, recruited higher education students as study participants, and used traditional computers to run their systems instead of mobile/smart devices. This review has also revealed that offering personalized learning content was the most widely adopted learning support, followed by personalized learning paths, personalized interfaces, personalized diagnosis and suggestion, personalized prompts or feedback, and personalized recommendations (Xie et al., 2019). The most popular learning outcomes assessed in the research studies were simple cognitions (referring to learning achievements instead of higher-order thinking or collaboration), followed by "affection", which includes learning intention, self-efficacy, satisfaction/interests, and learning motivation. Reported learning outcomes were generally positive.

Additional systematic reviews also offer insights into ITSs as personalized learning systems. According to Mousainasab et al.'s (2021) systematic review of research between 2007 and 2017, the most popular educational field investigated in research projects was computer science, and condition-action rule-based reasoning was the most frequently adopted AI technique in intelligent tutoring systems. Prior to this time period, Kulik and Fletcher's (1990) meta-analysis of over three decades of research studies focused on the effects of ITSs on student learning. The meta-analysis reported robust and positive learning gains (moderate-to-large effect).

Overall, the literature offers evidence supporting adaptive learning technology, and researchers anticipate even greater future potential given the rapid advancement in mobile and smart devices (Mousavinasab et al., 2021; Xie et al., 2019). The future for adaptive learning technology holds high promise, and the effort is receiving generous support from foundations such as the Bill and Melinda Gates Foundation, and organizations such as the Association of Public & Land-Grant Universities (Cavanagh et al., 2020). However, adaptive learning systems have not yet been implemented broadly

(Cavanagh et al., 2020). The following section will thus address a potential use-case for adaptive learning, responding to the need for mobile learning.

Microlearning. Microlearning is a paradigm of learning that aims to bridge individuals' knowledge gap without the risk of cognitive overload by offering small but well-planned chunks of learning units and activities for easier digestion and management (Giurgiu, 2017; Kovachev et al., 2011; Sun et al., 2015b). Microlearning utilizes various online and open sources, such as Wikipedia, Twitter, TikTok, YouTube, or other social media and platforms, for small-sized (or "bite-sized") learning units (Kovachev et al., 2011).

The advantages of microlearning are multifold (Jomah et al., 2016). For example, as the learners can use fragmented short time blocks, they can learn their target knowledge anytime from anywhere (Jahnke et al., 2020). They also can access resources just-in-time (Brunk et al., 2012), and in a short period of time (Sun et al., 2018). In addition, as the learners interact with manageable micro-sized contents during microlearning, they do not have to suffer from attention span constraints (Sun, Cui, Yong, et al., 2015) or cognitive overload (Bruck et al., 2012). With these advantages, especially with respect to flexibility and versatility, microlearning has shown great potential for remedial and enrichment learning in online environments, as well as in face-to-face and blended learning settings (Semingson et al., 2015). Microlearning has also been suggested as a solution to lower the dropout rate and to enhance learning continuity when in informal learning environments, such as Massive Open Online Courses (MOOCs) (Sun et al., 2018).

Chapter Summary and Research Potential

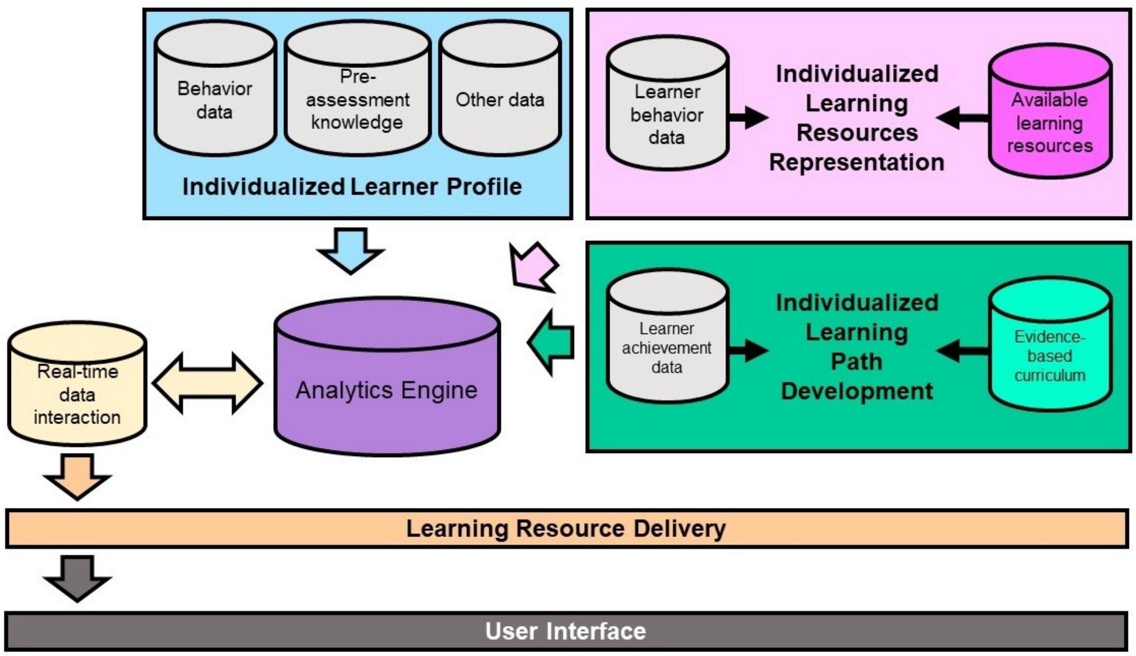
This literature review began by showing the educational challenges and opportunities that China faces through a brief historical review of education systems in China. Deeper learning, as an ideal of education, was then reviewed, followed by adaptive learning technology as an approach to implement deeper learning.

While the benefits of deeper learning can be achieved regardless of instructional mode (e.g., online vs face-to-face), facilitating deeper learning in online learning settings requires greater instructional design efforts (Crawford & Schmidt, 2004; Gandara, 2015). For example, as deeper learning requires social feedback and interaction between students and the instructor, the tools responding to this have to be situated in the chosen CMS (Wickersham & McGee, 2008). Similarly, as deeper learning necessitates student engagement, the online curriculum designer has to allow the CMS to be individualized to consider the students' learning needs to motivate and challenge students and allow them to take ownership of their own learning experience (Wickersham & McGee, 2008). Additionally, as conceptual learning promotes deeper learning but must be paired with the learning of facts (Kauffman, 2015), instructional design should target increasing both factual and deeper learning. The need for students to develop their own strategies for interacting with the curriculum, such as planning, staying organized, and staying motivated (Kauffman, 2015), also requires instructional design to support both procedural and metacognitive learning. Therefore, the curriculum and instructional design for online deeper learning implementations must be well-conceptualized while still adaptable and flexible, allowing the student to customize their unique learning context (Wickersham & McGee, 2008).

As with the realization of deeper learning, providing students with appropriate learning resources that meet their learning needs in real-time is a great challenge. In an effort to respond to this challenge, Sun et al. (2015) proposed a framework that combines adaptive learning and microlearning via learning analytics (see Figure 4).

Figure 4

Framework of Adaptive Micro Learning System



As seen in Figure 4, an analytics engine could be used in conjunction with processes that take information from the user interface, and use the data to develop individualized learning profiles, individualized learning paths, and an individualized plan for learning resource representation based on learner and resource metadata. Could the above framework of the adaptive microlearning system help to realize deeper learning? Could an adaptive microlearning system mitigate the unbalanced educational resource issue in terms of the rural-urban gap in China? These questions will guide a study as outlined in the subsequent methodology section.

Chapter 3

Methodology

Overview

The overall purpose of this research was to study an innovative online adaptive microlearning prototype as a way of improving deeper learning in middle school Chinese students. This chapter is organized in the following sequence. First, the research questions and hypotheses are presented, and this is followed by a description of the adaptive microlearning innovation, and the features of the prototype developed for study. Second, the structure of the study is presented, including research setting, participants and sampling, measurements and data collection, and data analysis strategy.

Research Questions and Hypotheses

This study aimed to address the potential of adaptive microlearning as a means to improve deeper learning. Specifically, this study focused on middle school students in rural areas of China who are educationally disadvantaged due to the remoteness of their location. With this overall research aspiration, the current study examined the potential of a novel online adaptive microlearning system designed for deeper learning to assist students in rural areas of China. In particular, the current study investigated the degree to which a prototype online adaptive microlearning module, when used to supplement formal face-to-face classroom instruction, promoted rural Chinese students' deeper learning experiences.

Below is a detailed research question for this study. All of the research question components are descriptive except for the first one, for which a null and alternative hypothesis will be presented.

1. Does the adaptive microlearning module promote the learning engaging in *active learning*?

   $H_0 1$: The mean number of questions participants ask ($\mu 0$) is equal to the population mean ($\mu = 0$).

   $H_A 1$: The mean number of questions participants ask ($\mu 0$) is higher than the population mean ($\mu > 0$).

2. Does the adaptive microlearning module inspire the learner to create *learner context*?
3. Does the adaptive microlearning module create an *engaged learner*?
4. Is the adaptive microlearning module associated with *learner ownership*?
5. Is the adaptive microlearning module an example of *technology-supported learning*?
6. Is the adaptive microlearning module an example of *intuitive design*?
7. Does the microlearning module lead the learner to participate in *engaged activities*?
8. Is the adaptive microlearning module associated with *facilitative learning practices*?

   $H_0 2$: The mean post-test score is equal to the mean pre-test score.

   $H_A 2$: The mean post-test score is higher than the mean pre-test score.

Figure 5 summarizes these deeper learning principles (DLPs) as described in Wickersham and McGee (2008), along with ways DLPs are expressed in online curricula.

Figure 5

Deeper Learning Principles and How They can be Applied in Online Curricula

Deeper Learning Principle	Characteristics summarized from Wickersham & McGee (2008)	Examples in Online Learning
1. Active Learning	Real-world problems, inquire and analyze, produce and collaborate	Learner is provided real world examples in learning activities.
2. Social Learning	Interacting with others, receiving real-time feedback, authentic assessment	Learner communicates synchronously or asynchronously.
3. Learner Context	Learner makes choices about what to learn, uses models, schemas, and real-world data	Learner has many multimodal options available for learning.
4. Engaged Learner	Learner has explicit objectives, chooses how to learn, uses multimodal information sources	Learner sets self-goals with the platform and tries to meet them.
5. Learner Ownership	Learner sets goals/deadlines, makes choices about end-products, provides learner-identified solutions	Learner responsible for choosing elements to help them learn
6. Technology-supported	Can be accessed anytime/anywhere, multimodal options, public and private functions	Access from anywhere on any device
7. Intuitive Design	Intuitive navigation, clear learner prompts, icons are interpretable, criteria for performance/completion	Online activities are intuitive and easy to navigate
8. Engaged Activities	Post public assignments or products, collaborative functions, opportunity for application/synthesis	Activities require user interaction with multimodal online elements
9. Facilitative Learning Practices	Knowledge update and acquisition, learner responsiveness, involved learning	Improvement pre-test to post-test

As shown in Table 1 and Figure 5, Wickersham and McGee (2008) defined nine DLPs, and provided some characteristics to describe these DLPs. Figure 5 also provides examples of how these DLPs would be incorporated into an online adaptive microlearning module.

If an adaptive microlearning module was designed specifically to increase the learner's experience of deeper learning, it is anticipated that all of these measures would be high in most users of the module (Wickersham & McGee, 2008). It is anticipated that active learning, engaged learner and engaged activities would be high because of the micromation feature of the microlearning module, which would provide a diverse set of realistic and interesting learning experiences for the learner (Wickersham & McGee, 2008). If the adaptive microlearning module has a social component, then social learning could also be facilitated (Wickersham & McGee, 2008). Learner context and learner ownership could be facilitated by the ability for the learner to control their experience of the adaptive microlearning environment (Wickersham & McGee, 2008). The module should be designed with a focus on technology-supported learning and intuitive learning, and should support openness to using learning activities available in the public domain (Wickersham & McGee, 2008). Finally, through active learning and learner-supported engagement, it would be anticipated that after the use of the module, the learner's knowledge retention would increase, showing evidence of facilitative teaching practices (Wickersham & McGee, 2008).

Study Method

This section will describe an instantiation of the adaptive microlearning module, which is called the Teaching Cell. Teaching Cells will first be described philosophically, in terms of how they are designed and how they function educationally. Next, this section will present the prototype Teaching Cell that was tested in this project, the Wu Zetian Teaching Cell.

Teaching Cells

The Teaching Cells system was designed and developed to deliver an online supplemental education for Chinese rural middle school students (Liu & Kush, 2015). The term "cell" was adopted because the units ("cells") in Teaching Cells are basic building blocks of knowledge, as cells in biology are building blocks of living organisms. Both cells in biology and Teaching Cells interact with and respond to their environments. As such, the contents of the cells in the system can evolve in response to learner interactions (e.g., how well different learners use the "elements" of the cell, or the units containing learning activities). As the modular building block approach (microlearning) can provide the learner more choices and pathways to learning, allowing them to feel more ownership of their learning (Wickersham & McGee, 2008), Teaching Cells adopted this approach to better promote deeper learning.

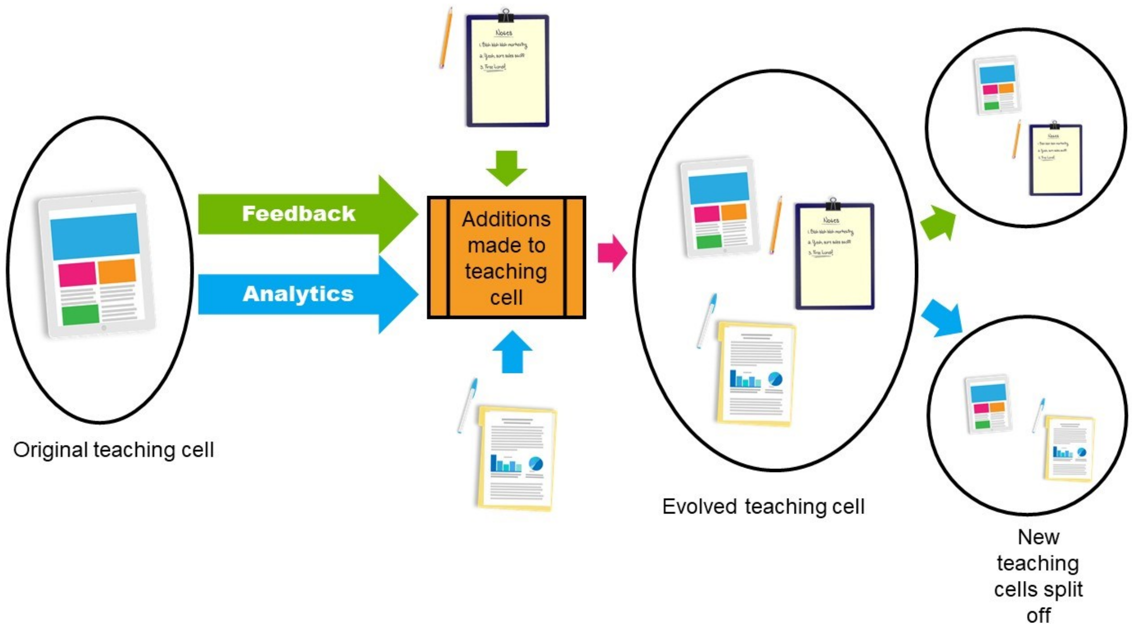
Features. The Teaching Cells system has been envisioned as being developed as an online platform for a curriculum promoting deeper learning to supplement rural Chinese middle school students' classroom learning. In order to succeed at this goal, Teaching Cells employ four main features: openness, evolutionary development, intellectuality, and micromation.

Openness. The openness feature refers to accessibility. The Teaching Cells system has been envisioned as being open to the public on the internet, allowing anyone who has an account to access it. The system is also open to any type of device, allowing any computing machinery, either stationary (e.g., desktop) or mobile (e.g., laptop, tablet, or smartphone), to have access. This openness reflects the deeper learning principle of "technology-supported" (Wickersham & McGee, 2008).

Evolutionary Development. As in cells in biology, the cells in the Teaching Cells system are also envisioned to grow and divide. They can grow to include more elements based on analytics and the availability of new material. This growth can also be followed by cell division. In addition to this ecosystem of cell growth and division, learners of the Teaching Cells system can also provide feedback through the evaluation component. The feedback can then further guide the evolution of Teaching Cells. The evolutionary development feature is depicted in Figure 6.

Figure 6

Evolutionary Development Feature

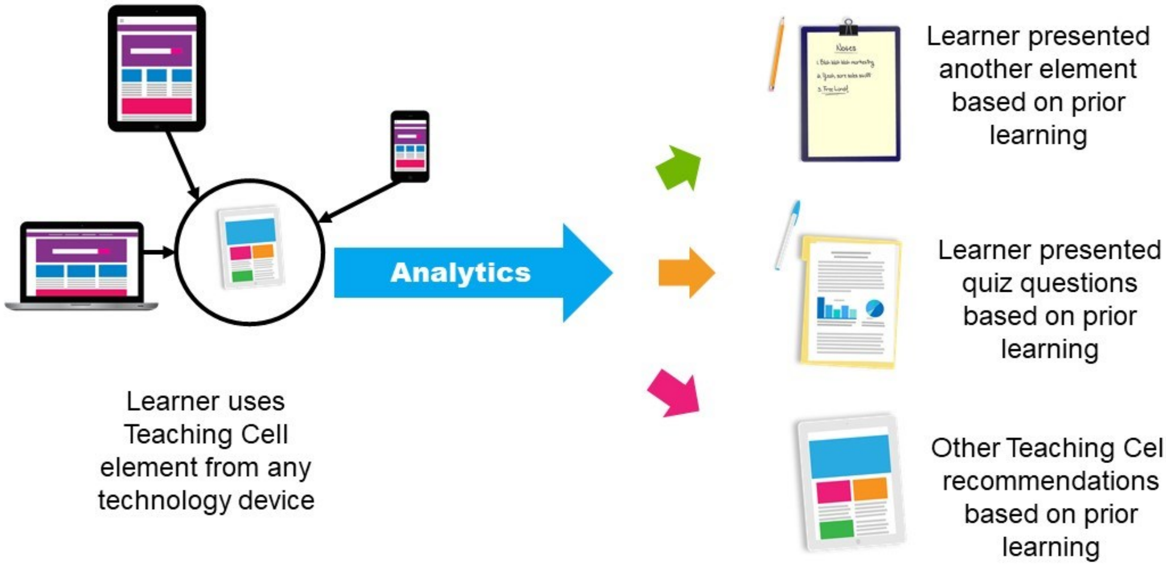


Note. The original Teaching Cell can have additions responding to learning analytics, student feedback and recommendations from content experts (e.g., teachers). Over time, the Teaching Cell can grow and be split into smaller Teaching Cells.

Intellectuality. In Teaching Cells, intellectuality refers to the adaptability for personalized learning. The Teaching Cells system is envisioned to adapt its display, the elements it is offering, and recommendations for learning activities based on each learner's prior experience with Teaching Cells on the platform, assessed via learning analytics (see Figure 7). Teaching Cells will be further optimized by responding not only to the technological environment (such as the device and browser used to access Teaching Cells), but also students' learning activity feedback.

Figure 7

Intellectuality Feature



Micromation. "Micromation" is a concept created for Teaching Cells and refers to "bite-sized" learning modules, called elements. The Teaching Cells system is envisioned to cover a multitude of complex learning topics, and a learning topic may be shared across multiple cells. A cell in the system focuses only on a small set of learning objectives, potentially covering a subset of a learning topic. The learning objectives may be broad or specific in their scopes. Via micromation, various types of "bite-sized" elements (e.g., lecture videos, readings, and games) relevant to meet each Teaching Cell's learning objectives can be presented to students. The micromation feature makes intelligent personalized learning possible, as it allows for analyzing the interaction between the learner and different elements in the system (see Figure 8).

Figure 8

The Micromation Feature

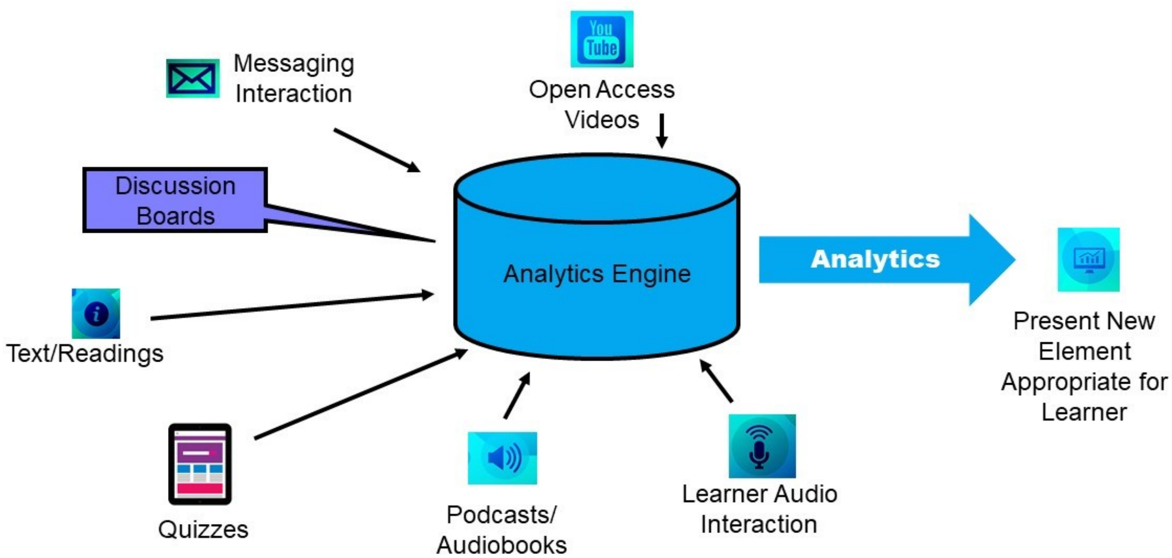
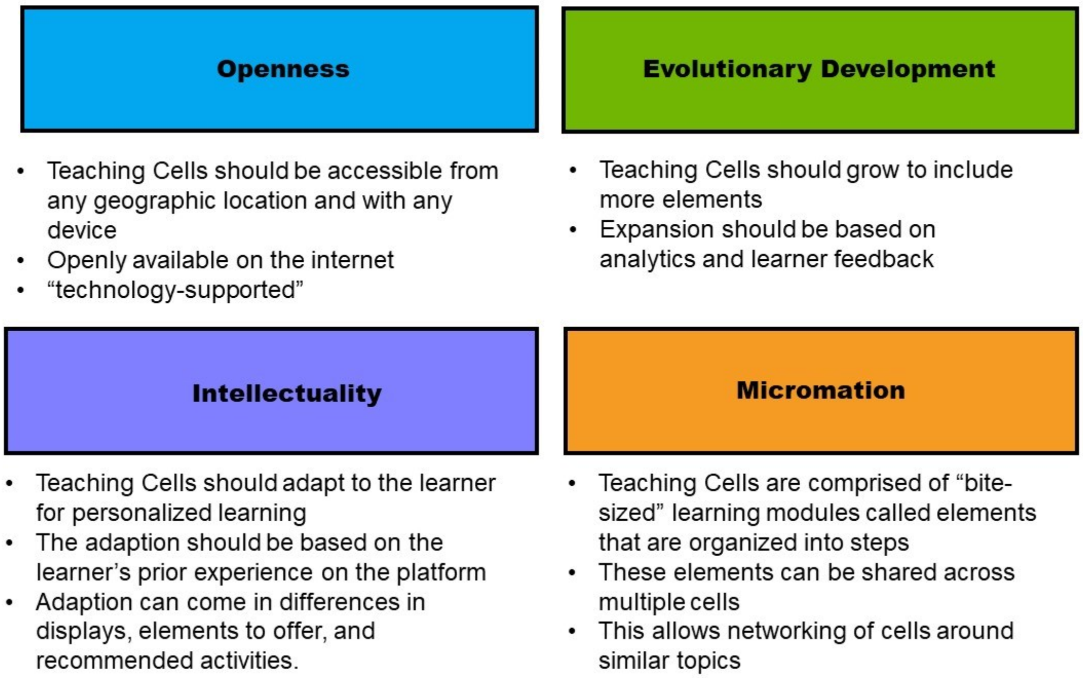


Figure 8 also addresses the openness feature, which allows elements that are not offered by the Teaching Cells system to be adopted via analytics. The analytics engine collects information about the use of these open elements. It will use that information to develop recommendations for other elements and Teaching Cells, and will suppress recommendations that are not felt to be appropriate for the learner.

Figure 9 summarizes the features of the Teaching Cell.

Figure 9

The Four Features of the Teaching Cell



Steps in Teaching Cells . The backward design approach (Childre et al., 2009) was adopted when designing the prototype Teaching Cell. Each cell in the Teaching Cells system is envisioned to consist of a standardized set of steps (seven steps) to promote deeper learning: 1) pre-test, 2) ask questions, 3) guidance, 4) teaching, 5) exercise or practice, 6) post-test, and 7) evaluation. The prototype Teaching Cell followed these steps.

Each of these steps has elements associated with them. "Elements" refers to educational modules, tasks, or activities associated with the Teaching Cell step. Each step has different business rules about the elements. Figure 10 summarizes the relationship between the steps and the elements.

Figure 10

Teaching Cell Steps and Elements

Teaching Cell Step	Elements in Each Step	Element Attributes
1. Pre-test	Pre-test element	The pre-test element should be paired up with the post-test element to determine if knowledge uptake occurred.
2. Ask Questions	Ask Questions element	This element allows learners to post questions. The learner input can be used in analytics.
3. Guidance	One or more Guidance elements	One or more guidance elements can be used to engage the learner and provide them context.
4. Teaching	Multiple Teaching elements	One or more teaching elements can be used to engage the learner, to better meet their learning style, and to provide analytics for decision-support.
5. Exercise/ practice	Multiple Exercise/ Practice elements	As with teaching elements, one or more exercise/practice elements can improve engagement and analytics.
6. Post-test	Post-test element	Analytics from the post-test element paired with the pre-test element can determine the learning value of the Teaching Cell for the learner.
7. Evaluation	Evaluation element	Evaluation element allows learner to provide feedback about the Teaching Cell.

As can be seen in Figure 10, the seven steps are listed on the left, and the number and type of elements associated with each step are included in a column next to the list. The business rules for the attributes of the elements are also described. The purpose and nature of each step are described below.

Step 1: Pre-test. A pre-test is to be administered as the first step of the Teaching Cell. As shown in Figure 10, this step only has one element – the pre-test element. This pre-test provides an opportunity to assess the student's prior knowledge of the subject. If the student was already well-informed on some or all of the learning objectives, this assessment information would go into the analytics engine and created a personalized learning experience that focused on material related to the least known content. Later, to gauge knowledge uptake as a result of using the Teaching Cell, results from the post-test step would be compared to the results from the pre-test step.

Step 2: Ask questions. The Ask Questions step provides the student a forum to ask questions related to the learning objectives. Asking questions promotes deeper learning (Childre et al., 2009), and the questions that the student provides can go into the analytics engine to improve the student's personalized learning. As described in Figure 10, the Ask Questions element may be designed in different ways, but it there would only be that one element in this step.

Step 3: Guidance. In the third step, "Guidance" refers to information delivery of facts without relating them to applied knowledge. This guidance is necessary to teach correct terminology, and didactic information that is typically delivered in a lecture format in the classroom. Another example of guidance would be to provide the learner context of where the topic they are learning fits into a broader picture.

In Teaching Cells, guidance would be delivered in the à la carte style, so that there may be one or more elements for the guidance step (see Figure 10). Although the learner would undergo guidance in Step 3, the learner could stay in Step 3 for as short or as long of a time as the learner wants. Different elements could be recommended for the learner, but it would be up to the learner to choose what guidance to use.

It was envisioned that the learner would move from Step 3 (the Guidance step) to Step 4 (the Teaching step), but the learner might want to also navigate to Step 5 (the Exercises/Practice step), as well as navigate back to Steps 3 or 4. The learner would have the opportunity to access all these steps at once, although it would be recommended to follow steps sequentially.

Step 4: Teaching. During the teaching step, facts would be applied in demonstrated examples. As such, teaching is different from guidance, where only context would be provided. As with Step 3, teaching would be delivered in à la carte style. As described in Figure 10, like the guidance step, the teaching step would contain as many elements as felt necessary to provide adequate instruction for the topic. As part of the personalized learning, learners could choose what teaching elements (e.g., videos, games, and readings) to use from recommendations, and would be allowed to navigate back to Step 3 or move to Step 5 when they were ready.

Step 5: Exercises or Practice. During the exercise/practice step, learners would be allowed to practice what was just demonstrated or applied in Step 4. As with the guidance and teaching steps and as described in Figure 10, the exercises/practice step could have as many elements as felt needed to provide adequate instruction. Different exercises could be employed for different subject domains (e.g., writing, math, and so on).

Step 5 aims to have the learner produce new ideas, work out equations, interact with peers, comment on ideas, and demonstrate other applications of new knowledge. Gamification could play a role in some practice elements with built-in incentives such as points, leveling up, or prizes. Learners completing elements from Steps 3, 4, and 5 could opt to move on to Step 6.

Step 6. Post-test. The post-test in Step 6 would mirror the pre-test, and as indicated in Figure 10, would only include only the post-test element. Post-test scores would be compared to the pre-test to assess the learning gained through Steps 1 through 5. Learners who moved on to Step 6 from Steps 3, 4, and 5 could go back to these previous steps; however, they could reuse the Teaching Cell from Step 1 after completing the final step (Step 7).

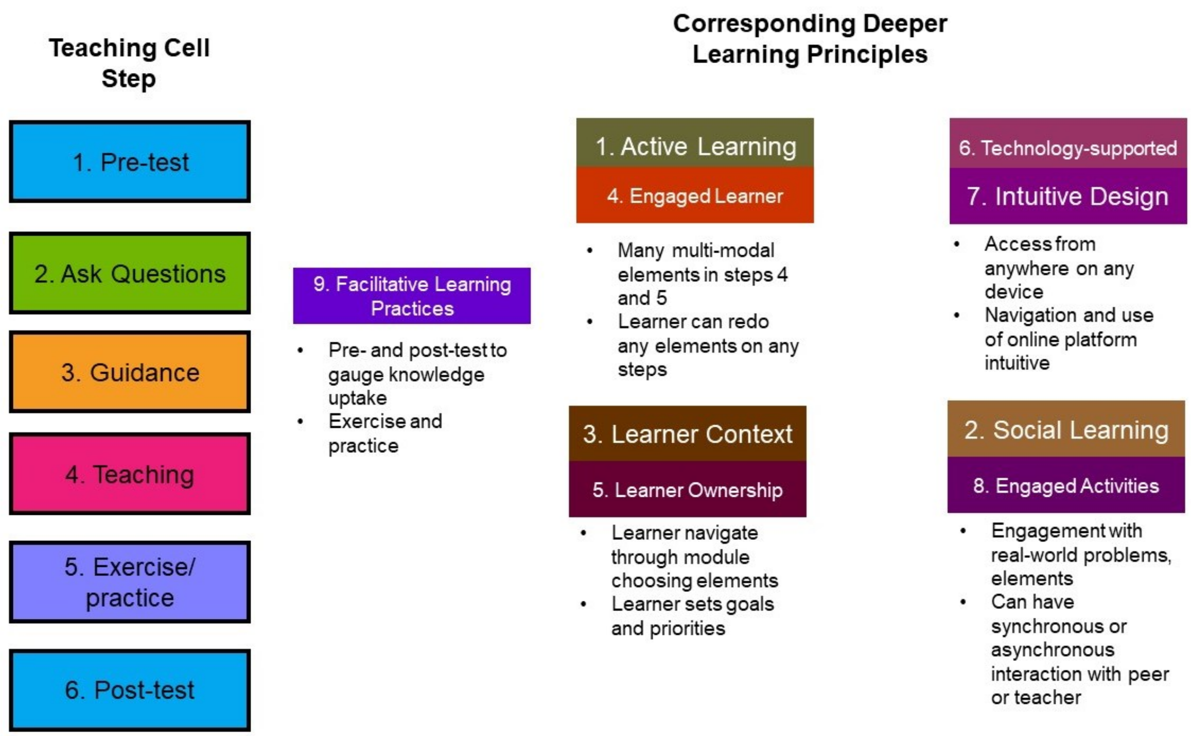
Step 7. Evaluation. In this last step, learners would be given an opportunity to evaluate the elements in the Teaching Cell and their experience with the cell. As described in Figure 10, this step would only have the evaluation element, and no other elements. The analytics engine would use the learner feedback from the evaluation step to improve the quality of the Teaching Cell.

The next section describes how Teaching Cells were designed to promote deeper learning.

Promoting Deeper Learning with Teaching Cells. As stated before, deeper learning engages the learner in actively exploring, reflecting, and even producing knowledge, rather than just recalling information (Wickersham & McGee, 2008). Teaching Cells were deliberately designed to promote deeper learning by allowing the learner to build upon their knowledge base. Figure 11 presents the association between Teaching Cell steps and deeper learning principles (DLPs).

Figure 11

Relationship of Teaching Cell Steps to Deeper Learning Principles (DLPs)



As shown in Figure 11, the process of the Teaching Cell encouraging DLPs is partly automated through analytics derived from pre-test scores, and manually implemented through the learner's ability to choose elements in Steps 3, 4, and 5 à la carte. Through the learner's actions when interacting with the Teaching Cell, without their knowledge, they would be working to personalize their learning experience through the analytics that would be used to present elements at different steps. This design feature would encourage complex learning processes that build upon existing knowledge. The ability to freely move among steps 3, 4, and 5 would allow learners to explore different learning activities actively. The exercise and evaluation steps would promote reflection and the production of knowledge.

As shown in Figure 11, there is not a direct one-to-one association between DLPs and Teaching Cell steps. Rather, different DLPs are emphasized throughout the Teaching Cell through its different features. Starting in the middle of Figure 11, the DLPs of active learning and engaged learner would be facilitated through the multi-modal elements available in Steps 4 and 5, which would allow the learner to navigate to, select, and use at their convenience. Moving to the right on the figure, the DLP of technology-supported would be facilitated in the Teaching Cell through the ability of the learner to access the Teaching Cell from any device (per the openness feature). Also, the DLP of intuitive design would be implemented through developing a platform for the Teaching Cell that makes navigation and utilizing the various elements associated with each step intuitive. This intuitive design would be implemented differently depending upon the technological platform used, but must be an attribute of the Teaching Cell.

Moving down in Figure 11, the DLP of social learning would be incorporated into the Teaching Cell through the ability of learners to interact with an instructor or peers. Also, the DLP of engaged activities would be fulfilled in the Teaching Cell through the various elements on Steps 3, 4 and 5 that would provide engagement in solving real-world problems. Moving to the left on Figure 11, the DLPs of both learner context and learner ownership would be facilitated in the Teaching Cell through forcing the learner to take control of their use of the Teaching Cell. It would be up to the learner to navigate from step to step as they would like, and to set their own goals and priorities for completing the elements.

Finally, moving to the left on Figure 11, the last DLP of facilitative teaching practices would be fostered in the Teaching Cell through the pre- and post-test steps. By comparing the learner’s performance in these steps, it could be determined if learning was facilitated through the Teaching Cell. If it was not, considerations should be made to improve the Teaching Cell, and to specifically focus on improving the teaching and practice/exercise steps.

So as a summary, active learning, a component of deeper learning, refers to solving real-world problems, inquiring about and analyzing new ideas, and other types of engaged learning as described by Wickersham and McGee (2008). Active learning would be emphasized in Steps 4 and 5 of the Teaching Cell, where the application of knowledge would be modeled and learners would engage in exercise and practice. Reinforcement would be automated in online feedback and via gamification. Active learning in the Teaching Cell would ultimately be learner-centric.

Another component of deeper learning described Wickersham and McGee (2008) comes from interaction, or social learning. The Teaching Cell would take advantage of the internet and online tools to promote deeper learning. Social interaction could be limited to peer interaction, or Teaching Cell modifications could be made to promote teacher-learner interaction to promote deeper learning. Interaction could be facilitated in Step 2, where learners had the opportunity to ask questions in a forum or chat room. Social interactions could be made a part of Step 5, where learners could engage in exercise and practice activities that involve interacting with peers. The final evaluation step also offers opportunities for interaction and social engagement.

Wickersham and McGee (2008) also pointed out that deeper learning has the components of learner ownership, where learners feel responsibility for their educational experience, and adaptability, where learning tasks adapt to the learners’ needs. They also highlighted that deeper learning includes personalized learning, where the learner can feel they are having a customized learning experience. The Teaching Cells system is designed to allow students to choose their learning pathways with respect to Steps 3, 4, and 5, through which they can gain ownership of the learning experience. Learners could also choose to participate in learner-engaged assessment online and either "lurk" or directly engage socially. The Teaching Cells system would also be adaptable and flexible; as such, each learner could have a unique experience during their learning journeys. The choices afforded in Teaching Cells would promote a personalized learning experience, and analytics would further improve learner experience.

The Teaching Cells system is not the first system designed to promote online deeper learning, nor will it be the last one. As such, even with the best effort to accommodate individual students' learning needs, Teaching Cells may not be suitable for all learners. For example, it is possible that some learners may avoid using Teaching Cells because they prefer face-to-face learning, or because they do not have adequate technological competence. Learners who are not interested in learning the topic may resist engaging in practice activities. Shy learners may not actively interact with peers socially in Teaching Cells. To be motivated to engage in learning within a learner-centered personalized learning environment, learners have to possess the necessary knowledge to engage in the learning activity and have the necessary regulation of their cognition (Hannafin, Hannafin, & Gabbitas, 2009).

Prototype Cell: Wu Zetian

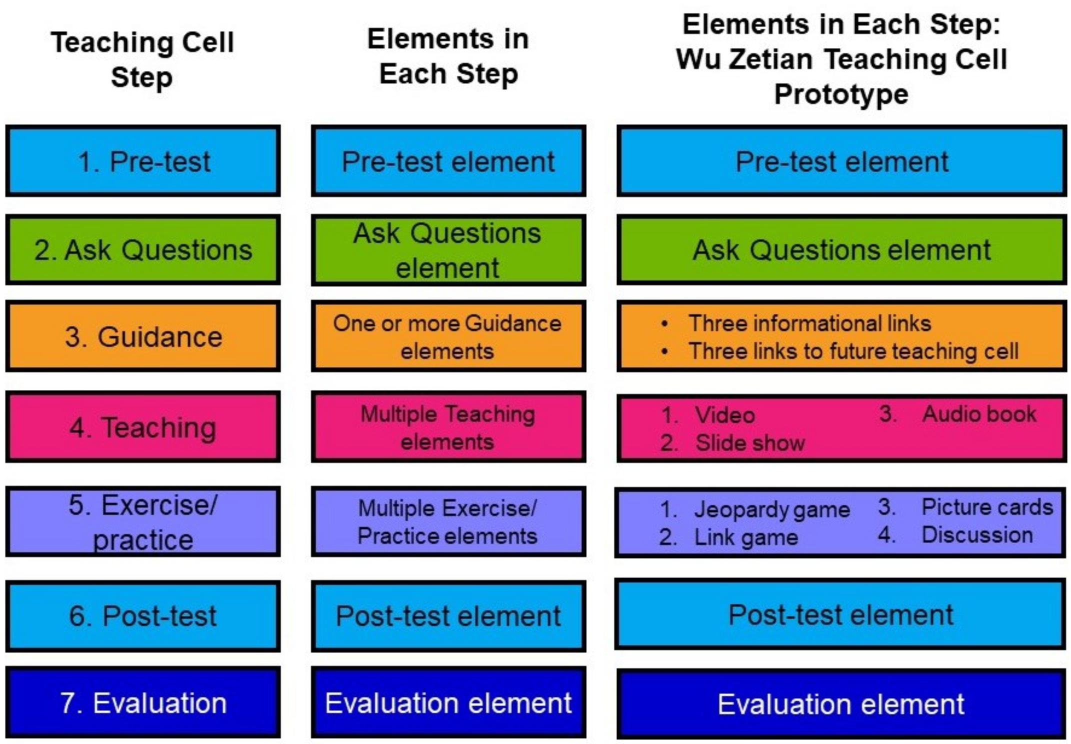
The prototype Teaching Cell designed for testing focused on teaching about Wu Zetian, the first empress in Chinese history. It was based on a teaching curriculum aimed at seventh graders in China that should be delivered over the seventh grade year (Ministry of Education, Peoples Republic of China, 2020). The prototype was tested in eighth graders in rural China, so they had all been exposed to the information before. The topic was chosen based on a review of competing educational technology platforms that were developed and multiplied during the COVID-19 pandemic in China. One example is Onion Academy, which is an online education platform providing interactive teaching videos and game-oriented learning to middle school students in China (CB Insights, n.d.). Onion Academy can be accessed online (https://www.alibabacloud.com/customers/onion-academy), and an online company profile can be accessed online also (https://www.cbinsights.com/company/yangcong). These platforms emphasize lessons in mathematics and English, and it was observed there was a lack of lessons in history and other topics. In order to fulfill this unmet need, a prototype Teaching Cell based on Wu Zetian was developed.

The components of the Teaching Cell developed followed the features and steps delineated previously about Teaching Cell design. The elements of the Teaching Cell were designed with an analytics component. While it was anticipated that in the future, this Teaching Cell will multiply and divide into other related Teaching Cells, it was not anticipated that this would be a fully automated process. Some human interaction would be needed to achieve optimal design. However, in order to do that, analytic information about Teaching Cell usage would need to be available. For this prototype, future Teaching Cells were envisioned but not designed, and analytics was collected in anticipation of developing future Teaching Cells. The modular microlearning design of the Teaching Cells prototype will allow for the splitting of this Teaching Cell and the evolution of more Teaching Cells in the future.

Figure 12 provides a summary of the steps and elements included in the prototype Wu Zetian Teaching Cell.

Figure 12

Steps and Elements in Prototype Wu Zetian Teaching Cell



As shown in Figure 12 and described earlier, Steps 1, 2, 6, and 7 only had one element each, because those steps only have one element. Next, as described in Figure 8, Steps 3, 4 and 5 had multiple elements. Step 3, guidance, had informational links and links to future Teaching Cells; Step 4, teaching, had three different teaching elements;

and Step 5, exercise/practice, had four elements. How those elements were designed and implemented in the Teaching Cell will be described in detail.

First, this section explains how the four features of the Teaching Cell – openness, evolutionary development, intellectuality, and micromation – were included in the design of the Teaching Cell. Next, the elements included in the Teaching Cell (as shown in Figure 12) will be described.

Features of the Prototype Teaching Cell.

This section describes the elements included in the prototype Teaching Cell.

Openness.

The prototype Teaching Cell was designed to be accessible on the internet. Learners could access a link to the login to the prototype Teaching Cell from any type of device: tablet, smartphone, desktop, or laptop. The online platform adjusted automatically to the type of browser that the learner was using.

Evolutionary Development.

As described earlier, this individual prototype was not part of a Teaching Cells system yet – it is only one prototype. However, because of the testing, there were data gathered about use of the different elements. This provides information on which to base evolutionary development of this and associated Teaching Cells as depicted in Figure 2. Analytics can provide information about which elements were being used more than others, as well as where the elements may have failed to teach the material as evidenced by post-test results and evaluation feedback. Therefore, while the prototype Teaching Cell did not undergo evolutionary development during the study, the study provided information to guide evolutionary development in the future.

Intellectuality.

The intellectuality feature in the prototype Teaching Cell could not be included in the prototype. This was because this was the first prototype, and it was the first attempt to build such decision-support into the technology. The questions posed in the Ask Questions step (Step 2) could be used to provide guidance as to which Practice/Exercises (Step 5) to present first to the learner when they got to that step, which could be automated. However, this automation was not included in the prototype due to technological limitations.

Micromation.

As described earlier, the elements of the prototype Teaching Cell included open items, meaning learning elements available openly on the internet. The Teaching Cell platform allowed for analytics based on the usage of these open items. That way, data could be gathered and analysis done on utilization. The prototype Teaching Cell also included some elements designed by the researcher in order to complete the full functionality and purpose of the Teaching Cell. These were described later, under the individual steps.

Steps and Elements of the Prototype Teaching Cell.

As described earlier, a backward design (Childre et al., 2009) was used when designing Teaching Cells. This required that first, learning objectives were delineated. The learning objectives chosen for the prototype Teaching Cell were:

At the end of this teaching cell, the learner should be able to:

1. State three ways in which Empress Wu Zetian’s leadership surpassed the leadership of many male Chinese leaders.

2. Name the two dynasties to which Empress Wu Zetian was connected, and explain how her rule served as a bridge between them.

3. Identify two main achievements ascribed to Empress Wu Zetian, and describe how they changed the path of Chinese history.

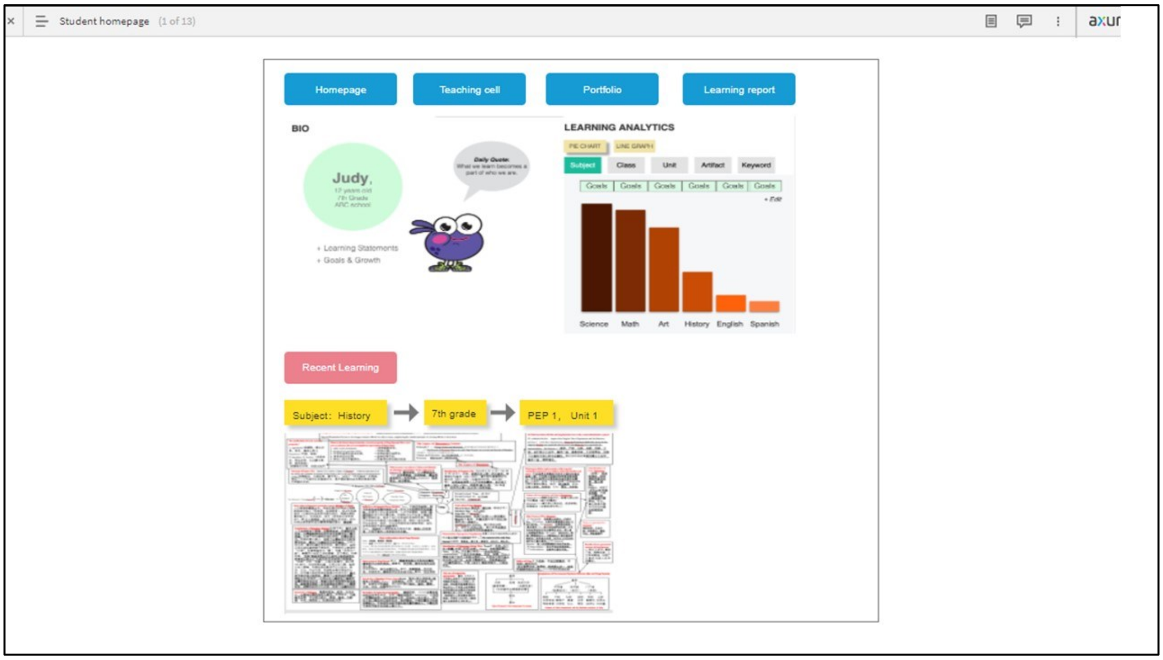
As described earlier, each cell in the Teaching Cell system consisted of a standardized set of steps (seven steps) to promote deeper learning: 1) pre-test, 2) ask questions, 3) guidance, 4) teaching, 5) exercise or practice, 6) post-test, and 7) evaluation. How each step was instantiated in the prototype is described in this section.

The Teaching Cell prototype, as mentioned before, focused on the reign of Empress Wu Zetian in Chinese history. This was a lesson from grade seven of the official government curriculum. A non-functioning prototype was initially developed in online software to help guide the development of the functional prototype which was actually used in testing. This section describes each step in the prototype Teaching Cell, including the elements on each step and how they function, with images displayed from the non-functioning prototype.

Entering the Teaching Cell. The prototype Teaching Cell starts with an attractive dashboard (see Figure 13).

Figure 13

Dashboard to Enter Prototype Teaching Cell

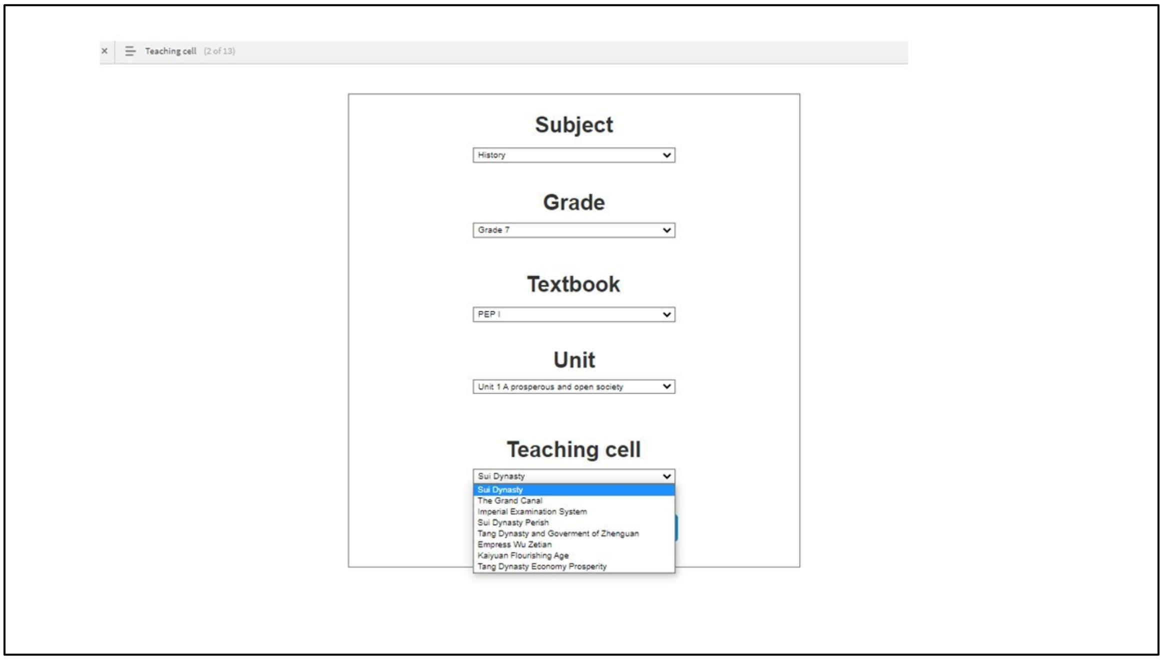


This dashboard provides the learner a comprehensive overview of their learning progress, and access to other Teaching Cells and activities. Here, the learner could choose to go into the Teaching Cell area by clicking a button.

Choosing a Teaching Cell. Once inside the Teaching Cell area, the learner could choose which Teaching Cell to access (see Figure 14).

Figure 14

Choosing a Teaching Cell



Although Figure 14 appears to present a menu of choices, only the prototype Teaching Cell would actually be available. Once the learner accessed the Teaching Cell, they would automatically be placed in Step 1: Pre-test.

Step 1: Pre-test of Teaching Cell. In the prototype Teaching Cell, a question bank of twelve questions that directly relates to the learning objectives of the Teaching Cell was used to challenge the learner in the pre-test as well as in the post-test. Table 2 provides the questions and answers for this question bank.

Table 2

Question Bank for Pre- and Post-test Elements

Q. no.	Question wording	First incorrect answer	First incorrect answer explanation	Second incorrect answer	Second incorrect answer explanation	Third incorrect answer	Third incorrect answer explanation	Correct answer	Correct answer explanation
1	Which reign did Wu Zetian inherit?	Xuanzong (Kai Yuan)	The reign of Xuanzong came after the reign of Wu Zetian.	Gaozong	This was actually the reign of Wu's husband, and started two kings' era with Wu.	Zhongzong	This was actually the reign of Wu's son, who only ruled one year before abolished.	Taizong (Zhen Guan)	Taizong is the era of Zhenguan and Wu's first husband.
2	Which reign came after Wu Zetian?	Taizong (Zhen Guan)	The reign of Zhen Guan actually came before the reign of Wu Zetian.	Gaozong	This was actually the reign of Wu's husband, and started two kings' era with Wu.	Ruizong	This was actually Wu's son, and he followed many Wu's suggestions.	Zhongzong	Wu's son, after Wu Zetian died, he came back to palace and became the next emperor, even though he only ruled 5 years.

Table 2 (continued)

Q. no.	Question wording	First incorrect answer	First incorrect answer explanation	Second incorrect answer	Second incorrect answer explanation	Third incorrect answer	Third incorrect answer explanation	Correct answer	Correct answer explanation
3	Which of these developments happened under Wu Zetian?	Taxes were increased for the first time in 50 years.	Actually, under Wu Zetian, taxes were reduced.	She revitalized fishing practices.	Actually, she was involved in agriculture and business, but not fishing specifically.	She insisted on keeping old traditions of power.	Actually, she fought against old power to develop new ways to lead, and include other voices.	Agriculture and business expanded.	Empress Wu Zetian oversaw a society that was stable, where agriculture, manufacturing and business development were achieved.
4	Which of these facts are true about Wu Zetian?	Wu Zetian was the third empress in China.	Actually, Wu Zetian was the only empress in China.	Wu Zetian was only a teenager when she ascended to the throne.	Actually, Wu Zetian was the oldest empress to ascend to the throne.	Wu Zetian was seen as weak, with her husband being more powerful.	Actually, Wu Zetian is seen as one of the most powerful leaders in Chinese history.	She ruled for 15 years as empress.	Wu Zetian indeed ruled for 15 years, from 690 to 705

Table 2 (continued)

Q. no.	Question wording	First incorrect answer	First incorrect answer explanation	Second incorrect answer	Second incorrect answer explanation	Third incorrect answer	Third incorrect answer explanation	Correct answer	Correct answer explanation
5	Which of these facts is major evidence that Wu's deeds outweigh her faults?	She led the country in using the empirical exam system to select talents.	Wu is not the first emperor to use empirical exam system, as this started in the Sui Dynasty.	She replaced a weak and sick husband to rule the government.	This is not major evidence, but it may be the reason why she successfully became empress.	She placed emphasis on talents and promoted employing people with better abilities.	This is not major evidence because it only happened in Wu Zetian's later governing.	She built the "bridge" between Zhenguan and Kaiyuan.	Building this bridge is the most important impact Wu Zetian made during her reign.
6	Who is Wu's first husband?	Gaozong	Gaozon was actually Wu's second husband, and he is also Taizong's son.	Zhongzong	Zhongzong is actually Wu's son.	Xuanzong	Xuanzong is actually Wu's grandson.	Taizong	Taizong was Wu's first husband, even though they were not romantic.

Table 2 (continued)

o.	Question wording	First incorrect answer	First incorrect answer explanation	Second incorrect answer	Second incorrect answer explanation	Third incorrect answer	Third incorrect answer explanation	Correct answer	Correct answer explanation
7	When did Wu become the empress and change title of the reign name?	AD.637	Wu began her reign in AD 690. In AD 637, Wu became the wife of Taizong.	AD.655	Wu began her reign in AD 690. In AD 655, Wu became the queen of Gaozong	AD.674	Wu began her reign in AD 690. In AD 674, Wu Zetian started to rule in the era of "two kings", but Gaozong was still the emperor.	AD.690	Wu became the empress and started her Zhou reign in AD 690.
8	What did Wu Zetian innovate in the educational examination system?	She implemented the empirical exam system to select talents.	This exam system actually started in the Sui Dynasty, which was before the Tang Dynasty.	She expanded the number of test subjects.	Actually, not Wu Zetian but Taizong expanded the number of test subjects.	She added poems to the exam as a subject.	Actually, Xuanzong added poems to the exam system, not Wu Zetian.	She added a military examination to the exam system.	Wu divided the exam into two parts, and added a new military examination to the original literature-only exam system.

Table 2 (continued)

Q. no.	Question wording	First incorrect answer	First incorrect answer explanation	Second incorrect answer	Second incorrect answer explanation	Third incorrect answer	Third incorrect answer explanation	Correct answer	Correct answer explanation
9	What did Wu name her reign?	Tang	This is not correct, as Tang is the name of the reign before Wu Zetian.	Wu	Wu is Wu Zetian's family name, but not her reign name.	Sui	This is not correct, because the Sui name came before the Tang dynasty.	Zhou	When Wu became empress, she changed from Tang to Zhou.
10	What kind of environment do you think Wu Zetian experienced?	Divided and socially turbulent	This is not correct, as during the earlier part of the Tang Dynasty, the society was stable, prosperous, and open.	Economically chaotic	This is not correct, as during the earlier part of the Tang Dynasty, the society was stable, prosperous, and open.	Socially strict	This is not correct, as during the earlier part of the Tang Dynasty, the society was stable, prosperous, and open.	Prosperous and open	During the earlier part of the Tang Dynasty, the society was stable, prosperous, and open.
11	Which is not Wu's suggestion based on her twelve suggestions?	Stop the war with the other kingdom.	This is not correct, because stopping the war with the other kingdom was one of her suggestions.	Banning brothels and gambling.	This is not correct, because banning brothels and gambling was one of her suggestions.	Use laborers more efficiently as farmers rather than servants.	This is not correct, because using labor more efficiently was one of her suggestions.	Develop poetry culture.	This is correct, as this does not happen until Xuanzong's reign.

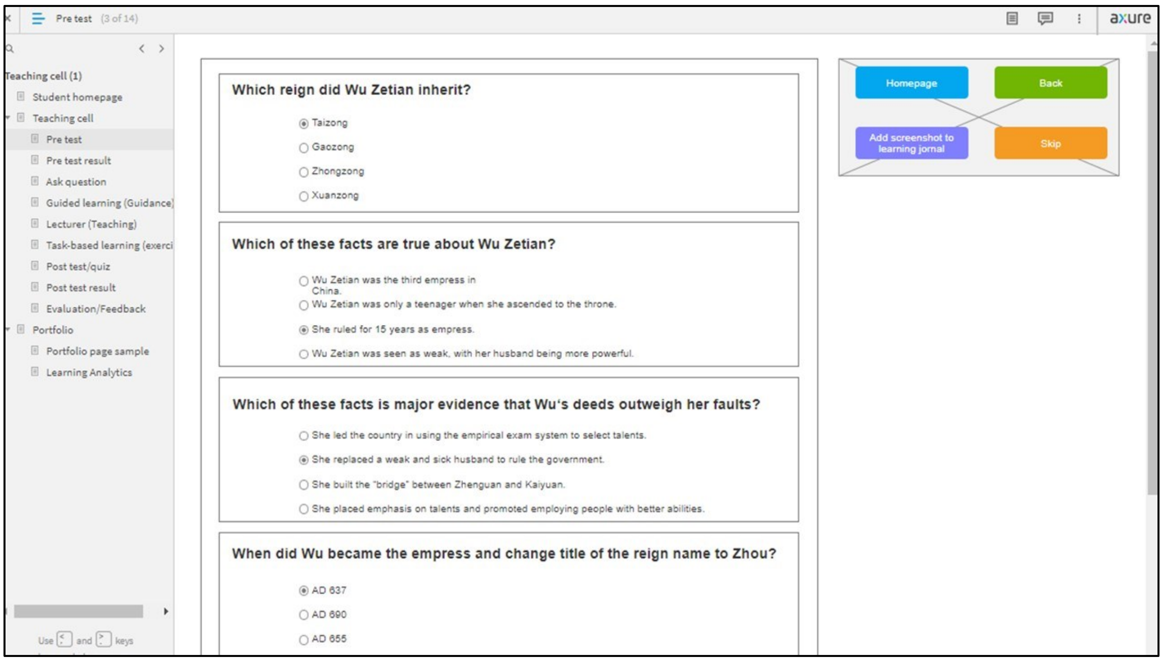
Table 2 (continued)

Q. no.	Question wording	First incorrect answer	First incorrect answer explanation	Second incorrect answer	Second incorrect answer explanation	Third incorrect answer	Third incorrect answer explanation	Correct answer	Correct answer explanation
12	What was Wu Zetian's reputation just before she died?	Extremely wealthy and selfish.	Wu Zetian was not known for being wealthy and selfish in her later years, but for being cold and cruel.	Very passive and sleepy.	Wu Zetian was not known for being passive or sleepy in her later years, but for being cold and cruel.	Very artistic and focused on beauty.	Wu Zetian was not known for being artistic in her later years, but for being cold and cruel.	She was known for being cold and cruel.	Although she had been very kind and generous throughout most of her rule, as she got older, she was accused of being cold and cruel, especially to prisoners.

This question bank was drawn from to present six questions in the pre-test, and six questions in the post-test (see Figure 15).

Figure 15

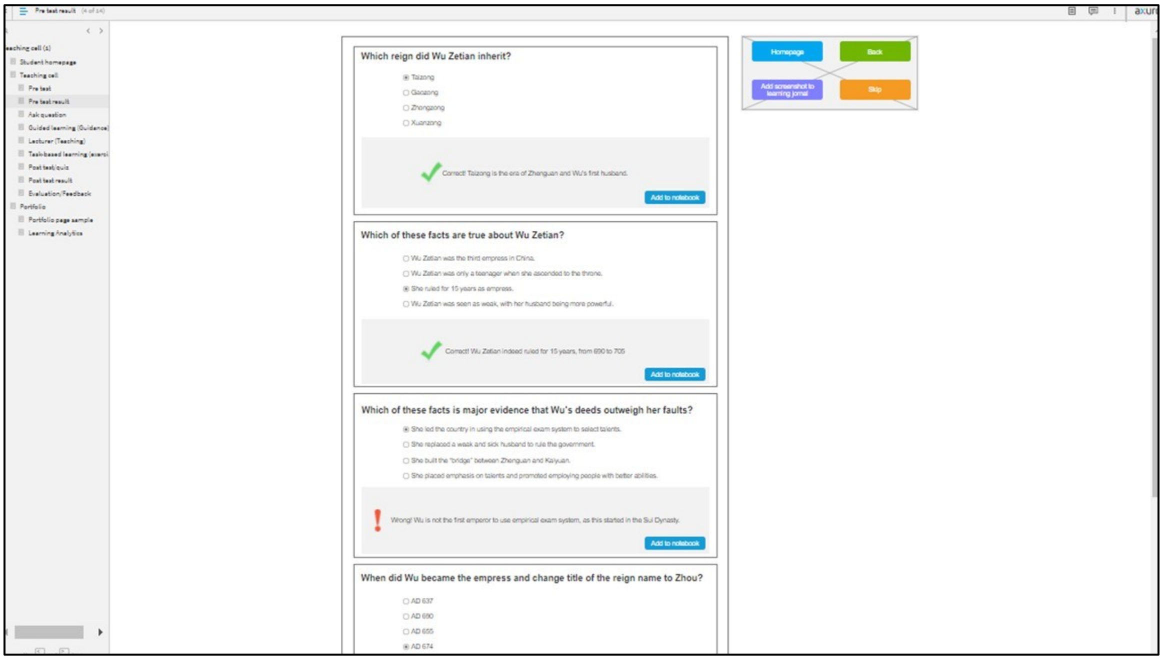
Pre-test Element from Prototype Teaching Cell



As shown in Figure 15, the pre-test would allow the learner to fill in some multiple-choice questions. They would immediately get feedback on their answer (see Figure 16).

Figure 16

Feedback from Pre-test Element



As is shown in Figure 16, the pre-test would make use of the feedback messages from Table 2 about the correct and incorrect answers. Although in the functional prototype, there was no decision-support based on the pre-test answers, in future Teaching Cells, these answers could add to the intellectuality of the Teaching Cell.

Step 2: Ask questions in Teaching Cell. Because the learners using this Teaching Cell were in middle school, based on the scaffolding teaching theory, the Ask Questions step was designed to create questions that the learners could select if they had that question to extend and support their learning. That way, learners of such a young age would not be expected to compose questions. This design feature allows for the ability to build in decision-support and intellectuality to this step. First, the questions that the learner selects from the list could be mapped to certain exercises that would benefit them, and analytics could be used to facilitate presenting these exercises to the learner. That way, the selected questions would be used as decision-support to provide the most appropriate exercises in the exercise/practice step that correspond to the learner's knowledge level about the topic. Second, simply choosing certain questions could indicate the learner's topical interests. This could provide the opportunity for analytics to use to recommend future teaching cells that would be of interest to the learner.

In consideration of these topics, Table 3 provides information about the questions that were presented in the Ask Questions step, and how they could relate to the rest of the decision-support in the Teaching Cell.

Table 3

Question Bank for Element in Ask Questions Step

Question number	Question wording	Primary exercise item	Current or future teaching cell
1	Was Empress Wu the only female leader in Chinese history?	Jeopardy Game	Current
2	How long was Empress Wu in a leadership position?	Link Game	Current
3	What did the city look like during Empress Wu's leadership?	Picture Cards	Current
4	What developments happened during Empress Wu's reign?	Jeopardy Game	Current
5	How did Empress Wu come to power?	Discussion	Tang Taizong
6	Did Empress Wu have a religion?	Picture Cards	Current
7	What do other learners think about Empress Wu?	Discussion	Current
8	What did items from Empress Wu's time in history look like?	Picture Cards	Current
9	What happened when Empress Wu was married to her first husband?	Jeopardy Game	Legacy of Zheguan
10	What do you think is the reason why the tomb of Empress Wu has no word?	Discussion	Current

Question number	Question wording	Primary exercise item	Current or future teaching cell
11	What did the territory map look like during Wu's reign？	Picture Cards	Current

Table 3 (continued)

Question number	Question wording	Primary exercise item	Current or future teaching cell
12	What did Wu's palace look like?	Picture Cards	Current

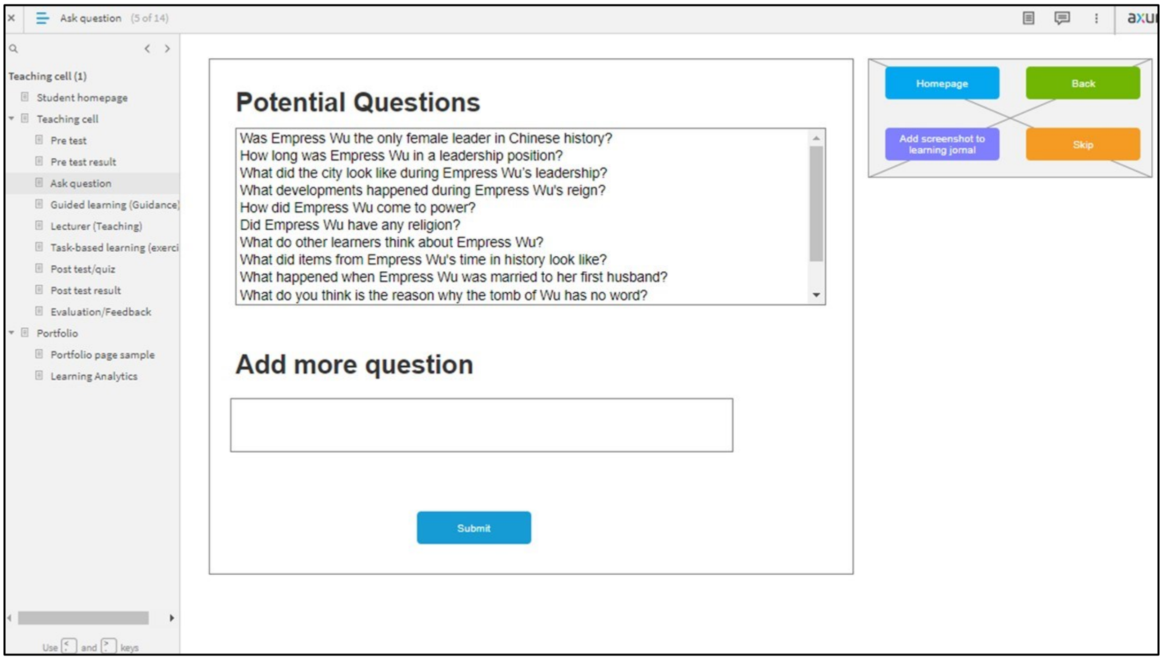
As can be seen in Table 3, 12 questions were developed. The column titled "Primary Exercise Item" indicates which of the four elements available on the exercise step – which were discussion, picture cards, Jeopardy Game, and Link Game would be the most appropriate to answer the learning desire indicated by the selected question. For example, a learner who wanted to know what other learners thought of Empress Wu Zetian would likely be more interested in a discussion activity, while a learner who wanted to know what Wu Zetian's palace looked like would probably be more interested in seeing picture cards first. Although all learners would have access to all elements, the use of the results from the Ask Questions step to determine the primary exercise item presented to the learner could provide an example of intellectuality in the Teaching Cell.

The column that says, "Current or Future Teaching Cell" indicates whether the question was answered in the current Teaching Cell, or another Teaching Cell. In the prototype, this information was not used, but in the future, this information can help determine which Teaching Cells are of greater interest to develop. This information could also impact recommendations from the Teaching Cell platform for the learner.

In the prototype Teaching Cell, the Ask Questions step is shown in Figure 17.

Figure 17

Ask Questions Step from Prototype Teaching Cell

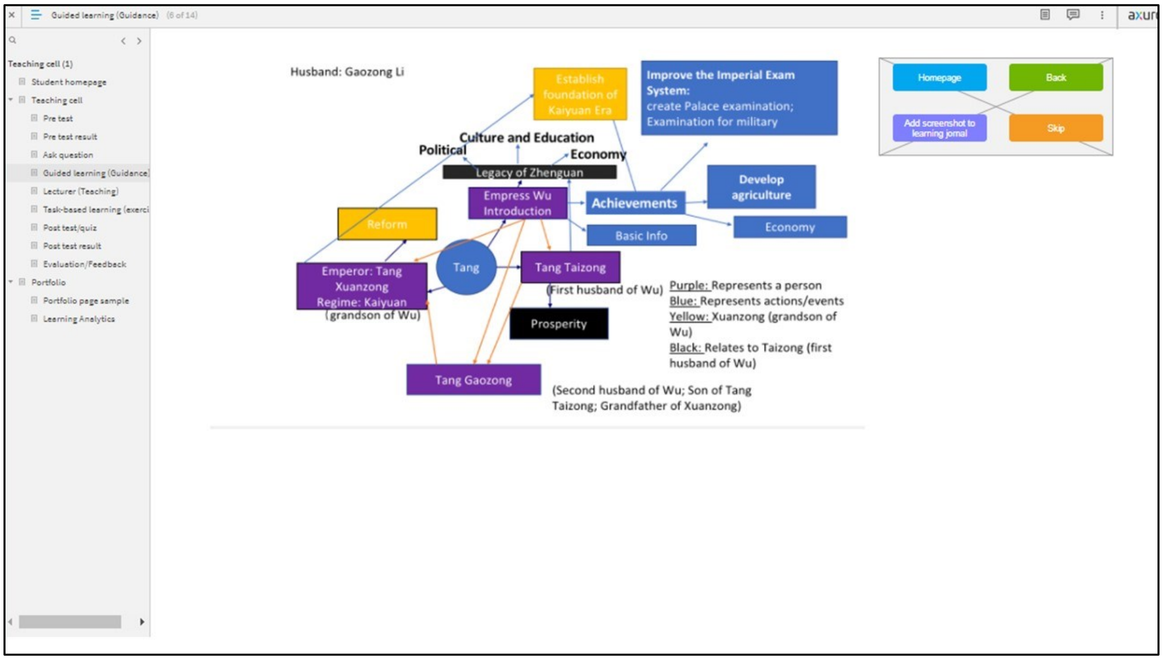


As shown in Figure 17, the learner selects which questions they want from the list, and adds those to the questions that they have.

Step 3: Guidance in Teaching Cell. In the prototype Teaching Cell, a guidance map was provided in this step (see Figure 18).

Figure 18

Guidance Map



The guidance step was intended to help the learner gain context and grasp the relative position of the topic they were learning to other topics. These boxes in Figure 18 represent elements on the guidance step, were color-coded to the type of topic, and behaved differently depending up on the type of topic (see Table 4).

Table 4

Specifications for Guidance Elements in Teaching Cell

Order	Box description	Box color	Type of connection	Wording or comment
1	Emperor: Tang Xuanzong Regime: Kaiyuan (grandson of Wu)	Purple	Informational link related to current teaching cell	The emperor who had a prosperous reign after Zhenguan. He was one of Wu's grandson. He became the emperor after Wu died and Wu's sons restored Tang as the reign's name. After these two sons died, he became emperor. Even though he is not directly after Wu's reign he is the next emperor really ruling for years after Wu. That's also the reason why historical experts say Wu is the bridge between Zhenguan and Kaiyuan.
2	Tang Taizong (first husband of Wu)	Purple	Informational link related to current teaching cell	Wu's first husband. He made Wu move into the palace when she was only 15 years old, and give her a beautiful name: "Meiniang". But they were not romantic. After he died, Wu moved to a temple to live until Gaozong brought her back to the palace to become the empress.
3	Tang Gaozong (Second husband of Wu)	Purple	Informational link related to current teaching cell	Wu's second husband, who is Taizong's son, and supported Wu to become a woman who has power. Also known for the "two kings" era, during which he and Wu ruled the country together
4	Legacy of Zheguan	Black	Lead to another teaching cell (future)	This could actually lead to a whole series of related teaching cells about the Zhenguan era.
5	Achievements	Blue	Lead to another teaching cell (future)	This could actually lead to a whole series of related teaching cells about the related achievements (agriculture, economy, etc.).
6	Establish foundation of Kaiyuan Era	Yellow	Lead to another teaching cell (future)	This could actually lead to a whole series of related teaching cells about the Kaiyuan era.

In Table 4, the column "Box Description" indicates all the boxes (elements) on the guidance step, and the box color is listed in the next column. The type of connection to the Teaching Cell is described in the third column. For example, if the learner were to click on the guidance box that was purple and said, "Tang Taizong", they would be provided information through a link to the current Teaching Cell with the information in the "wording or comment" column being displayed. On the other hand, if the learner were to click the blue Achievements box, in the future, they would be led to a different Teaching Cell. However, in the current version, there was no special behavior.

Step 4: Teaching in Teaching Cell. The teaching step could have as many elements as needed, and the prototype included three teaching step elements (see Table 5).

Table 5

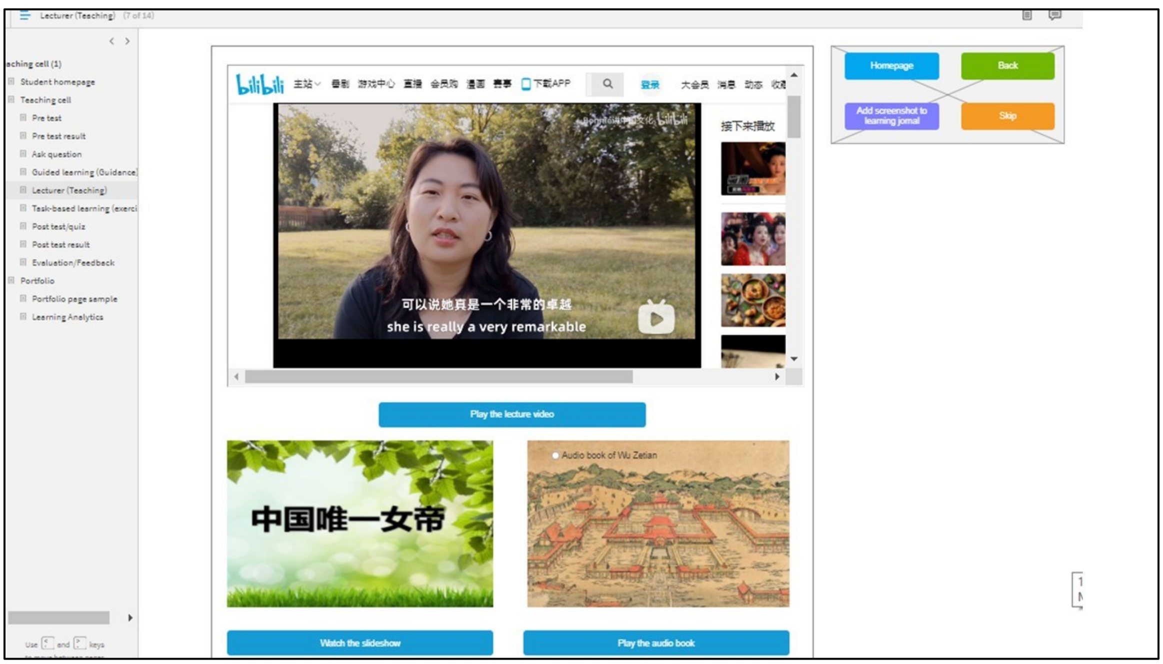
Elements in Teaching Step

Order	Item	Description
1	Video	This video has both English and Chinese. The transcript was made from the video, which is from an external source. The video includes all the information needed to answer the teaching cell learning objectives. The video is in English, but Chinese subtitles can be added.
2	Slide Show	This is an extremely comprehensive, Chinese-language slide show that includes many details and facts that was found from an external source. It also has all the information to answer the teaching cell learning objectives, it is just much longer and more detailed than the video.
3	Audio Book	Most of the people using the teaching cell will likely speak Chinese, so this is a Chinese translation of the audio book.

As can be seen by Table 5, there were three potential elements in the teaching step – a video, a slide show, and an audio book about the topic of Empress Wu Zetian. These items are openly available, and emphasize the openness feature of the Teaching Cell. These present the information in Chinese because the learners speak Chinese. Chinese transcripts that are translated into English are available in Appendix A. Figure 19 shows the teaching step of the Teaching Cell.

Figure 19

Teaching Step of Prototype Teaching Cell



As can be seen in Figure 19, the video, slide show, and audiobook elements could be accessed by the learner at their own direction.

Step 5: Exercises or Practice in Teaching Cell. As described earlier, there were four elements in the exercises or practice step of the prototype Teaching Cell: Jeopardy game, link game, picture cards and discussion. These are described in Table 6.

Table 6

Elements in Exercise/Practice Step

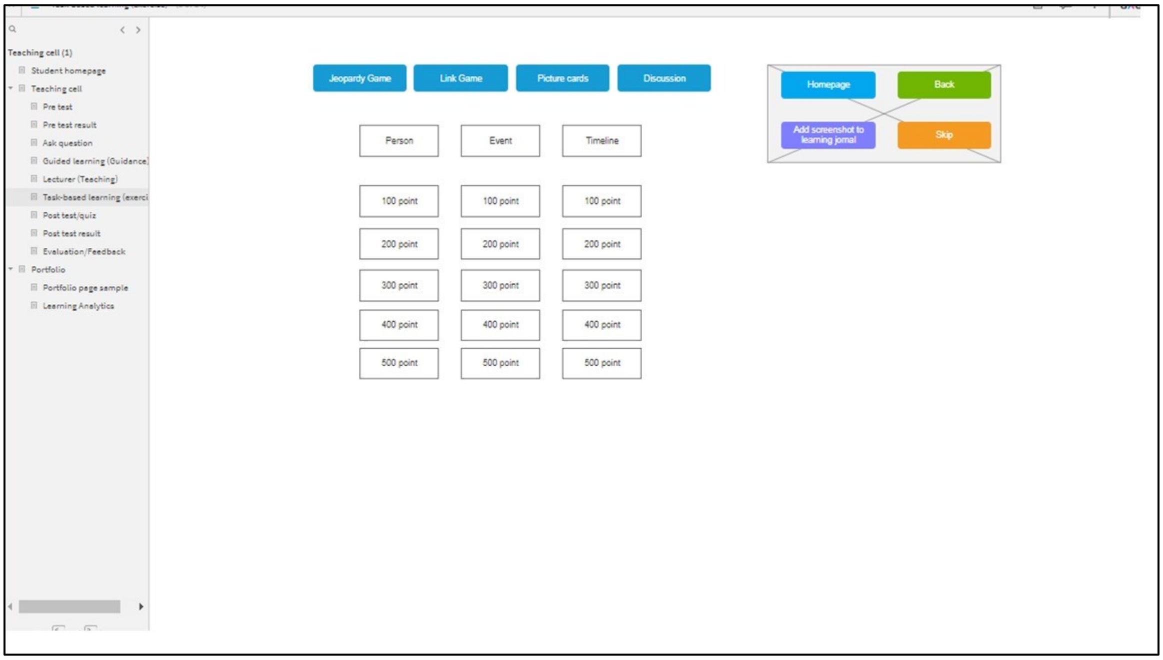
Order	Item	Description
1	Jeopardy Game	Game styled like Jeopardy which provides questions and answers, where the learner earns points.
2	Link Game	In this game, 18 cards are laid out with facts on them. The goal of the game is to pair up cards with related facts to make them disappear.
3	Picture Cards	To add a more visual exercise, picture cards were created. This is a slide deck with actual images related to the topic with text annotating them.
4	Discussion	Learners are presented with four topics, and they are asked to enter their thoughts about the topic. After clicking submit, they see a report about what other students said.

As can be seen in Table 6, these activities were highly engaging. The Jeopardy game was a trivia game, and the link game had the learner pairing up cards with facts on them. The picture cards activity had the learner flipping through cards with images on them that were annotated, and the discussion had the learner adding information about what they felt about a topic.

As described earlier, all four elements would be available to all Teaching Cell learners, but it was originally intended that a primary practice/exercise activity would be recommended based on the results of the Ask Question step, to demonstrate intellectuality. For example, according to Table 3, if the learner chose the question, “Was Empress Wu Zetian the only female leader in Chinese history?” they would be recommended to first try the Jeopardy game activity (see Figure 20).

Figure 20

Jeopardy Game Element



The reason they would be recommended to this the game element depicted in Figure 20 is because this was a trivia game, and they would be expressing the learning preference that they like trivia. This game was similar to the one on television, where the player chooses a trivia question they can answer, and if they get it right, they get points. These trivia questions were all about the material for the Teaching Cell (see Table 7).

Table 7

Trivia in Jeopardy Game Element

Order	Topic	Points	Jeopardy correct answer	Jeopardy question	Incorrect 1	Incorrect 2
1	Person	100	Taizong	Who was Wu Zetian's first husband?	Gaozong	Ruizong
2	Person	200	Zhongzong	Who came after Gaozong as next emperor?	Ruizong	Xuanzong
3	Person	300	Gaozong	Who ruled during the two king era?	Taizong	Zhongzong
4	Person	400	Ruizong	Who followed Wu's 12 suggestions?	Gaozong	Zhongzong
5	Event	100	Agriculture, manufacturing and business	Which areas were developed during Wu's reign?	Agriculture, mining, and business	Agriculture, manufacturing, and culture
6	Event	200	Added military examination	What was the innovation of the exam system during Wu's reign?	Started empirical exam	Expanded more subjects
7	Event	300	Stop the war with the other kingdom	Which was Wu's military policy?	Expand the frontier	Sending her daughter to marry into neighboring kingdom
8	Event	400	The population decreased	Which event does not belong to Wu's reign?	Two kings happened in same reign	Creating a society with prosperity
9	Timeline	100	AD.690	When did Wu became the empress?	AD.655	AD.637

Table 7 (continued)

Order	Topic	Points	Jeopardy correct answer	Jeopardy question	Incorrect 1	Incorrect 2
10	Timeline	200	AD.655	When did Wu became the queen of Gaozong?	AD.637	AD.674
11	Timeline	300	AD.637	When did Wu got name "Wumei"?	AD.655	AD.690
12	Timeline	400	AD.664	When two king ruling period start?	AD.655	AD.690

However, if in the Ask Questions step, the learner chose the question, “How long was Empress Wu Zetian in a leadership position?”, as shown in Table 2, they would be first presented with the link game when they got to the exercise/practice step, which is shown in Figure 21.

Figure 21

Link Game

In this game, facts were paired up, and the learner would have to identify the pair. Pairs of facts that were mirrored in the Ask Questions step connected to this exercise here. Table 8 provides the facts involved in the link game.

Table 8

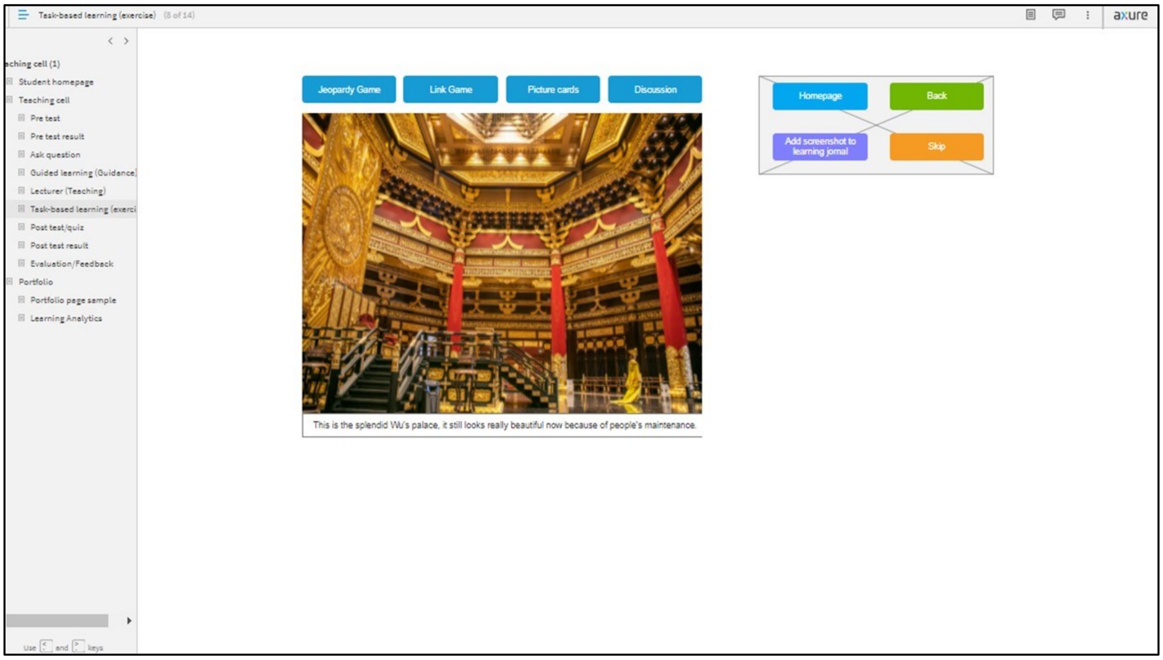
Link Game Element

Order	First choice	Second choice
1	Wu Zetian became queen	AD 655
2	Gaozong	Wu Zetian's husband and son of Taizong
3	Wu's prime minister	Direnjie
4	Taizong	Zhenguanzhizhi
5	Starting Zhou reign	AD.690
6	Wu Zetian ended her reign	AD.705
7	The person as "bridge" between two prosperous reigns	Wuzetian
8	Xuanzong	Kaiyuanshengshi
9	Two kings ruling at the same time era	AD.664

If the learner chose the question, "What did the city look like during Empress Wu's leadership", per Table 2, they would be referred to start the exercise/practice step with the picture card activity, as shown in Figure 22.

Figure 22

Picture Card Element



As shown in Figure 22, the picture card element provided annotated picture cards including some fun facts about the learning material in the Teaching Cell. A list of images and their annotations are in Table 9.

Table 9

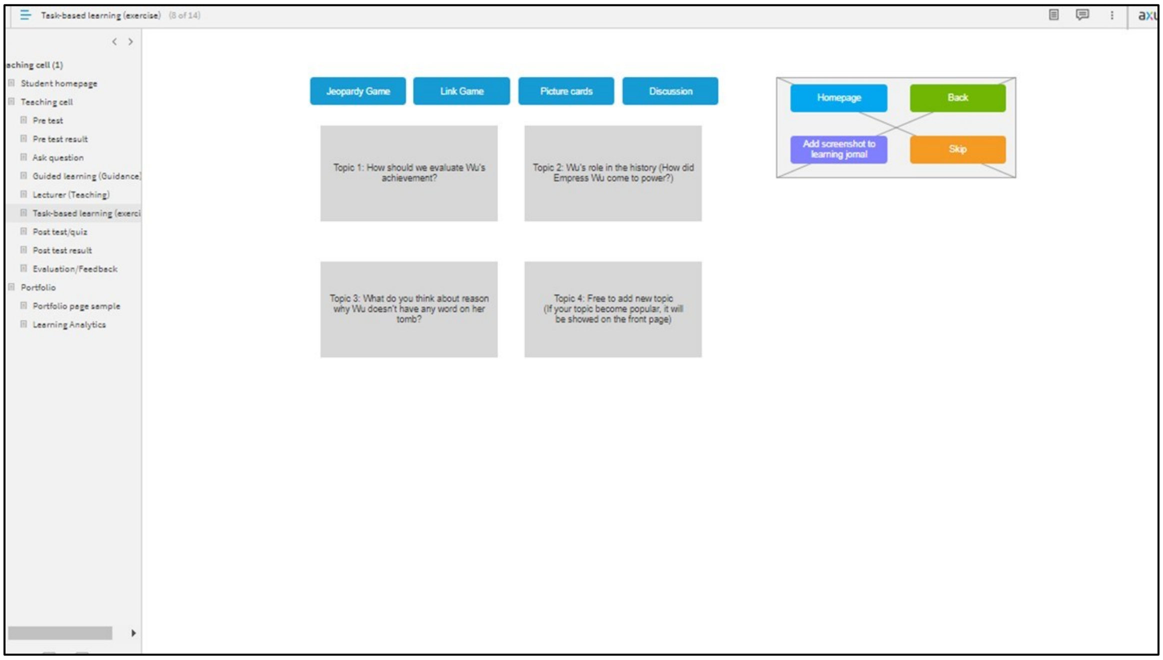
Picture Card Annotations

Order	Picture	Description
1	Wu Zetian	This is a drawing of Wu Zetian. Based on historical expertise, Wu was very tall woman and pretty. That's why she got the name, "Wumei" from Taizong, which means super beautiful.
2	Luoyang City	This is the sand table to show what does Luoyang (the capital city of Wu's reign) looks like. It was called Ziwei City, and was the busiest and most flourishing city in the world at that time. The commerce and night life were very busy, and population was very large. This is also the only city that was called "god city" because of its beauty and buildings.
3	Wu's Palace	This is Wu's splendid palace. It still looks really beautiful now because of ongoing maintenance.
4	Buddha Building	During Wu's reign, she invested in carvings, and built Buddha statues for more luck. People still go to these huge groups of statues to make wishes. This big project started from the early years of Wu's reign and end when Wu Zetian died.
5	Territory map	Estimated territorial extent of Wu Zetian's empire.
6	Tomb of Wu	Wu Zetian's tomb is located to the east of Phoenix Gate. It is within the Qianling Mausoleum, which was built near Chang'an in 706 to house the remains of Tang Gaozong, Empress Wu, and other royal members of the Chinese Tang Dynasty. It is the large Blank Tablet or Wordless Stele. This tablet is 6.3 meters tall and weighs 98 ton. It has no inscriptions, but the sides of the tablet have carved dragons, and the top has carved oysters.

Per Table 2, if the learner were to choose the question, "How did Empress Wu come to power?", they would first be referred to the discussion element in the exercise/practice step (see Figure 23).

Figure 23

Discussion Element



In the discussion element, the learner was presented a choice of four discussion questions that they could choose to answer. Those questions directly related to the learning objectives to the Teaching Cell, and are listed in Table 10.

Table 10

Discussion Element Questions

Order	Item	Relates to objectives
1	Topic 1: How should we evaluate Wu's achievement?	3
2	Topic 2: What is Wu's role in history?	1, 2, and 3
3	Topic 3: Why do you think that Wu doesn't have any words on her tomb?	1 and 3
4	Topic 4: What related topic do you want to see covered? If your topic is chosen, it will be on the front page!	2 and 3

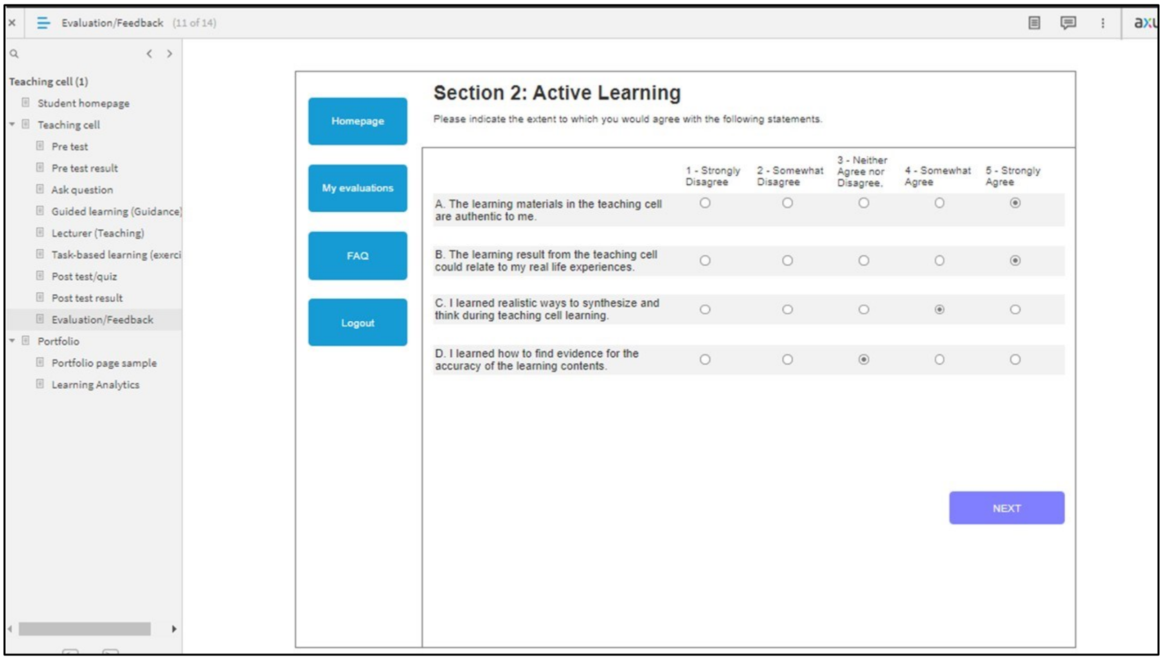
As can be seen in Table 10, these questions related to the learning material, and also promoted social learning. As it turns out, the intellectuality that was to be included in referring learners to primary practice/exercise elements was not possible in the functional prototype, so it was designed but not included.

Step 6. Post-test in Teaching Cell. The pre-test quiz element and post-test quiz element feedback used the same question bank as in Table 2, and looked as shown in Figures 15 and 16.

Step 7. Evaluation in Teaching Cell. The evaluation element was the last step, and looked like a survey to be completed, as shown in Figure 24.

Figure 24

Evaluation Element



The evaluation was designed to focus on the learner's evaluation of their experience in terms of the following DLPs: active learner, engaged learner, learner ownership, technology-supported, intuitive design, and engaged activities (see Table 1). Table 11 described the domains selected for the evaluation, and explained how they related to these DLPs.

Table 11

Domains and Related Deeper Learning Principles and Teaching Cell Steps in the Evaluation

Domain	Principle	Related Steps
Navigability	Intuitive design	Overall
How easy it was to use with their technology	Technology-supported	Overall
How realistic the problems were	Active Learning	Guidance, Teaching, Exercises
How much control they had over what they were learning	Learner Context	Guidance, Teaching, Exercises
How much they engaged with in the teaching cell	Engaged Learner	Ask Questions, Guidance, Teaching, Exercise
How responsible or self-directed they felt for their learning	Learner Ownership	Teaching and Exercise

As can be seen in Table 11, six domains were selected to relate to the six DLPs described. Table 11 also shows the related steps in the Teaching Cell where the domain came into play.

The evaluation was developed to be an online survey that was completed at the end of the use of the Teaching Cell, after the post-test. It was a series of statements preceded by the following instructions: Please rate how much you agree with each statement about the teaching cell, where 1 = Strongly Disagree, 2 = Somewhat Disagree, 3 = Neither Agree nor Disagree, 4 = Somewhat Agree, and 5 = Strongly Agree. A neutral response of “Neither Agree nor Disagree” was purposefully offered, so the learner could indicate neutrality on the topic. The statements included in the evaluation and how they related to the selected domains are listed in Table 12.

Table 12

Statements on the Evaluation and Their Related Domains

Domain	Statement
Navigability	The teaching cell was easy to navigate.
Navigability	I was able to find everything I was looking for in the teaching cell.
Navigability	The function of the different items in the teaching cell was intuitive.
How easy it was to use with their technology	I had no technological problems using the teaching cell with my technology.
How easy it was to use with their technology	I had trouble accessing the teaching cell.
How easy it was to use with their technology	I was successful using the teaching cell on different technology tools (Laptop, iPad, Smartphone).
How realistic the problems were	The learning materials in the teaching cell are authentic to me.
How realistic the problems were	The learning result from the teaching cell could relate to my real life experiences.
How realistic the problems were	I learned realistic ways to synthesize and think during teaching cell learning.
How realistic the problems were	I learned how to find evidence for the accuracy of the learning contents.
How much control they had over what they were learning	The teaching cell offers me ways to learn using different types learning materials.
How much control they had over what they were learning	The teaching cell let me skip what I already knew to save my learning time.
How much control they had over what they were learning	The teaching cell allows me to choose the learning activities that interest me to make learning more fun.

Domain	Statement
How much control they had over what they were learning	I could add my own ideas into the teaching cell.

Table 12 (continued)

Domain	Statement
How much they engaged with in the teaching cell	I feel learning materials in the teaching cell are very engaging.
How much they engaged with in the teaching cell	I felt confident when I did the test after learning using the teaching cell.
How much they engaged with in the teaching cell	I feel the teaching cell's learning materials are at the right level of challenge for me.
How responsible or self-directed they felt for their learning	I feel encouraged to share my ideas in the teaching cell.
How responsible or self-directed they felt for their learning	I feel encouraged to ask questions in the teaching cell.
How responsible or self-directed they felt for their learning	I feel the teaching cell allows me to control the pace of my learning without any pressure.

This concluded the seven steps to the prototype Teaching Cell. The next section reviews how DLPs were incorporated in the prototype Teaching Cell.

Deeper Learning Principles in Prototype Teaching Cell. Although many researchers and scholars agree that incorporating DLPs into curricula, including online curricula, improves learning, there was no official list of DLPs. As mentioned earlier, Wickersham & McGee (2008) provided a framework for thinking about DLPs when incorporating them into curricula. Table 1 presented in Chapter 2 provides a summary of their framework.

As shown in Table 1, Wickersham & McGee (2008) described nine DLPs with their attributes. This provided a framework for evaluating whether or not DLPs were incorporated into a curriculum. For example, under the principle “active learning”, there were several examples of activities that would denote active learning, such as solving real-world problems. If a curriculum incorporating solving real-world problems was provided to a learner, and that learner expressed that they perceived that they were learning via solving real-world problems, that would be evidence that active learning was taking place.

This section described how the various DLPs were incorporated into the prototype Teaching Cell used in the study.

Active Learning. There were several places where active learning could take place in the usage of the prototype Teaching Cell. First, the learner would be able to navigate freely through all steps and elements of the Teaching Cell, so they could actively choose which items to use. As shown earlier, there would be a variety of multi-modal elements on the guidance, teaching, and exercise/practice steps. These elements would be based on real-world problems and challenges.

There would be multiple ways that evidence of active learning could be gathered from a user's experience of the prototype Teaching Cell. One way would be to measure the number of questions they selected in the Ask Questions step, which would indicate their active engagement in the topic. Another way would be to ask the user about their active learning experience on the evaluation step.

Social Learning. Although social learning was anticipated to be built into future Teaching Cells, because of the singular nature of this prototype, social learning could not be incorporated into the prototype Teaching Cell. Therefore, it was not evaluated in the research.

Learner Context. The prototype Teaching Cell was online, so as the learner logged into the platform, they would already be in control of their learning context. As described earlier, the learner would be able to freely navigate through all steps and elements of the Teaching Cell, and would continue to control their context through their entire Teaching Cell user experience. In the guidance step, there would be links to information to help the learner understand the intellectual context of the knowledge they were acquiring. Also, as mentioned earlier, the learner would have the option in engaging in a variety of multi-modal elements available on the teaching and exercise/practice steps.

There would likely be many ways to measure the degree to which the learner experienced control over learner context when using the Teaching Cell. One way would be to gather analytics about their use of elements on the guidance step. Use of many elements would indicate their exploration of their own learner context.

Engaged Learner. As described earlier, the guidance, teaching, and exercise/practice steps would have a variety of multi-modal elements available with which the learner engaged. The learner could also have been engaged during the ask questions step, and through the pre- and post-test and evaluation steps.

One way to measure the level of engagement of the learner with the prototype Teaching Cell would be to measure how many elements were used by the learner in the teaching step, as that would indicate how engaged they were with learning the material. Another way to measure learner engagement would be to ask about it on the evaluation step.

Learner Ownership. Ultimately, a challenge with online learning would be having the learner take ownership and initiative over their learning experience. In a Teaching Cell, the learner must take ownership, because there would be no other facilitative device to navigate the learner through the cell. This would force the learner to engage with the Teaching Cell for navigation and discovery. It would encourage the learner to take ownership of their learning experience.

Perhaps the best measurement of learner ownership over their Teaching Cell learning experience would be observing how much they engaged in the exercise/practice step. Exercise indicates self-efficacy over learning the material, and suggests a feeling of ownership. The more engagement with the elements in the exercise step would indicate a higher level of learner ownership. Also, aspects of learner ownership could be asked about in the evaluation.

Technology-Supported. As described earlier, the Teaching Cell would be programmed so that it would be adaptive to whatever screen size or technology was used by the learner. That way, the learner could engage with all the components and have their learning activities be technologically supported.

When the learner would connect to the Teaching Cell online, information would automatically be available about what type of device they were using, where they were connecting from, and other metadata about their connection. These data could be used to evaluate how technology-supported the Teaching Cell is. Also, the learners could be asked about how technology-supported they perceived the Teaching Cell was during the evaluation step.

Intuitive Design. Today, there are many existing platforms for educational technology that could be evaluated in terms of intuitive design. The Teaching Cell prototype aimed to be ultimately intuitive in design, especially in terms of navigation, as the learner would be expected to completely own their educational experience. To that end, the only way it would be possible to tell if the user has an intuitive experience with the Teaching Cell would be to ask them during the evaluation step.

Engaged Activities. As described earlier, the guidance, teaching, and exercise/practice steps would have a variety of multi-modal elements for the user to select for learning engagement. The engagement in these could be measured to indicate evidence of more than one DLP, and engaged activities would fall in this category. Further, how engaged a user was with the prototype Teaching Cell could be measured in the evaluation step.

Facilitative Teaching Practices. Ultimately, the goal of any learning experience is to transfer knowledge. Facilitative teaching practices refers to the DLP associated with knowledge uptake, in the sense that the teaching activities developed – in this case, the steps and elements of the Teaching Cell – were successful in imparting knowledge. In the prototype Teaching Cell, the pre-test score compared to the post-test score would show the level of knowledge gained from the learner's experience with the Teaching Cell. This would probably be the best measure of evidence of facilitative teaching practices.

Study Structure

This section covers the structure of the experiment using the prototype Teaching Cell. First, the research setting, participants and sampling are covered. Next, the measurements that were taken during the experiment are described.

Research Design and Setting

The study was conducted using an experimental adaptive microlearning system called Teaching Cells, as described earlier. The design of the study was seen as a "proof-of-concept" design, in that it was only meant to determine if the innovation met basic functional criteria (Crocco et al., 2016; Dias, 2017). The design of the study was mixed-methods, meaning that there was a quantitative component as well as a qualitative component. For the quantitative component, data were gathered from users of the prototype Teaching Cell through two methods: 1) gathering data/analytics from Teaching Cell usage, and 2) analyzing data from the evaluation step, where users provided feedback about their learning experience. For the qualitative component, users who indicated on their evaluation that they were interested in further study participation were be contacted and interviewed about their Teaching Cell user experience.

Participants and Sampling

As mentioned earlier, this prototype Teaching Cell covered a part of the official Chinese curriculum for seventh grade about the history of Empress Wu Zetian. Therefore, the Teaching Cell was delivered to Chinese students currently in the eighth grade in September 2022 to test their knowledge retention from the regular curriculum, and to see if the prototype Teaching Cell could augment their knowledge.

The school from which participants were recruited was a primary school from the Changan district in Xi'an, China. This school had classes of approximately 50 students, and it was anticipated that six classes were able to participate, providing 300 students to test the prototype Teaching Cell. It was anticipated that these students would participate in this in September 2022. Prior to starting research activities, this study was approved by the Duquesne University Institutional Review Board (IRB) for the protection of human subjects in research (see Appendix B for IRB documentation). Data from their experience was analyzed to determine the level of deeper learning experienced by the students (described in next section).

Measuring DLPs in the Teaching Cell (Quantitative)

Table 13 describes how DLPs were measured among learners using the prototype Teaching Cell.

Table 13

Teaching Cell Measurements for DLPs

Principle	Prototype Teaching Cell characteristics	How measured for Teaching Cell	How measured	Step measured in
1. Active learning	The learner formulates questions in the "ask questions" step of the teaching cell, supporting inquiry. Learner has many choices for practice on real world problems during the "practice" step.	How many questions learner chooses in the "ask question" step. Learner will have 12 to choose from, so it will be 0 to 12.	From analytics (DV1) and evaluation (DV2)	Ask Questions
2. Social learning	Learner may submit feedback during one of the exercises and the evaluation.	Not applicable	Not applicable	Not applicable
3. Learner context	Learner makes active choices during "guidance", "teaching", and "practice" steps.	There are three "hot links" elements in the guidance step (which is a learning map). Researchers can count which of these learners click (count of 0 to 3).	From analytics (DV3)	Guidance
4. Engaged learner	Learner has access to multimodal information sources during "guidance", "teaching", and "practice" steps.	In Teaching step, how many elements learners engage with. There are three elements (video, slide show, audiobook), so learners can get 0 to 3.	From analytics (DV4) and evaluation (DV5)	Teaching

Table 13 (continued)

Principle	Prototype Teaching Cell characteristics	How measured for Teaching Cell	How measured	Step measured in
5. Learner ownership	Within each step, learner has complete ownership of the process with respect to pace, end-products, learner-identified problems, and documented reflection.	Did learners engage with Jeopardy? If so, what was their score. Did learners engage with Link Game? Did learners engage with Picture Cards? Did learners enter any Discussion text? For all learners, researchers will calculate a score of 0 to 4 for what learners engaged in. For Jeopardy, learners will have scores that can be used to better understand different student behavior.	From analytics (DV6) and evaluation (DV7)	Exercise
6. Technology-supported	Teaching cell can be accessed on the internet by any type of device.	Researchers will collect the type of technology the person was using to connect.	From analytics (DV8) and evaluation (DV9)	Overall
7. Intuitive design	The technological framework of the prototype will dictate this.	Intuitive Design will be one of the domains in the evaluation step.	From evaluation (DV10)	Evaluation
8. Engaged activities	Activities in the "guidance", "teaching", and "exercise" steps of the teaching cell will be public.	This already relates to what researchers are measuring for Learner Context, Engaged Learner, and Learner Ownership, so researchers will not do a separate measure for this.	Will use DV3, DV4, DV5, DV6, and DV7	Guidance, Teaching, and Exercise

Table 13 (continued)

Principle	Prototype Teaching Cell characteristics	How measured for Teaching Cell	How measured	Step measured in
9. Facilitative teaching practices	Objectives developed for the teaching cell are the focus of the content delivery. The pre- and post-test will measure knowledge acquisition.	Knowledge acquisition can be measured by comparing the "pre-test" and "post-test" steps. Researchers made a question bank of 10 questions, and we can give 5 at beginning and other 5 at end.	From analytics (DV11)	Pre-test and Post-test

As shown in Table 13, the intention was to measure all of the DLPs described in Table 2 with respect to the prototype Teaching Cell except social learning. That was because with one Teaching Cell, it was difficult to promote social learning, so it was felt that social learning would not take place to a high degree. The other DLPs were measured in learners through either analytics available from the Teaching Cell, or from items in the evaluation (see Tables 11 and 12), or both. These methods were described earlier, under the section discussing DLPs in the prototype Teaching Cell. However, for clarity, they will be repeated here.

As shown in Table 13, there were nine DLPs considered in this study, and the ones measured were quantified using multiple methods. Each method of measurement created a dependent variable (DV). In the table, the DLP of 1. Active Learning was measured by DV1 and DV2. The DLP of 2. Social Learning was be measured in this study. The DLP of 3. Learner Context was measured by DV3. The DLP of 4. Engaged Learner was measured my DV4 and DV5. The DLP of 5. Learner Ownership was measured by DV6 and DV7. The DLP of 6. Technology-supported was measured by DV8 and DV9. The DLP of 7. Intuitive Design was measured by DV10. The DLP of 8. Engaged Activities was measured using measurements already prepared for use for other DLPs, which included DV3, DV4, DV5, DV6, and DV7. Finally, the DLP of 9. Facilitative Teaching Practices was measured using DV11. How each of these DVs was measured was described below with respect to each DLP.

1. Active Learning. Referring to Table 13, the DLP of active learning was measured using analytics as well as through the evaluation items. For analytics, the prototype was programmed to collect how many questions were chosen in the “ask questions" step. Since there were twelve questions to choose from, this rendered a score of zero to twelve, which a higher score indicated higher levels of active learning (dependent variable [DV] 1). Also, as shown in Table 12, four items on the evaluation were devoted to the domain of active learning (DV2).

2. Social Learning. As described in Table 13, social learning was not measured.

3. Learner Context. Next, the DLP of learner context was measured from the guidance step. As described earlier, there were three elements which were "hot links" (links that could be clicked on for more information) on the guidance map presented to the learner. If the learner clicked on the links, they learned more information. Since there were three links, the learner could click on between zero and three items. The learner was assigned a score equivalent to how many items they clicked on, and a higher score indicated more learner context (DV3).

4. Engaged Learner. The DLP of engaged learner was measured using three statements from the evaluation as described previously (see Table 12, DV5), as well as analytics based on element use in the teaching step (DV4). The teaching step presented three elements: a video, a slide show, and an audio book. Through analytics, it was determined how many of these elements the learner used (zero through three) and this number was assigned as their score, with a higher score indicating a more engaged learner.

5. Learner Ownership. The DLP of learner ownership was also measured using three statements in the evaluation (see Table 12, DV7) as well as analytics, and the analytics were based on use of elements in the practice/exercise step (DV6). In that step, there were four potential elements for learning engagement: Jeopardy game, link game, picture cards, and discussion. All learners engaged in between zero and four of these elements, and were assigned a score based on this. Higher scores indicated higher levels of learner ownership.

6. Technology Supported. The DLP of technology-supported was also measured using three statements from the evaluation (DV9) and analytics from the prototype Teaching Cell (DV8). The analytics was basic, in the sense that the Teaching Cell just collected the type of technology the learner was using to connect (smartphone, tablet, etc.). These data provided descriptive information about the type of technology learners used to access the Teaching Cell.

7. Intuitive Design. Next, the DLP of intuitive design was assessed only using three statements from the evaluation (DV10), as it was not possible to evaluate this with analytics.

8. Engaged Activities. As described in an earlier section, the DLP of engaged activities was measured using DVs from other, related DLPs (see Table 13). The analytics and evaluation items already planned to assess the DLPs of engaged learner, learner ownership, and learner context also related to engaged activities, so those results were used to assess this DLP.

9. Facilitative Teaching Practices. Finally, the last DLP of facilitative teaching practices was assessed by comparing post-test results to pre-test results using analytics (DV11). If the learner’s score increased from the pre-test to the post-test, they were considered as having undergone facilitative learning.

User Experience Interviews (Qualitative)

At the end of the evaluation, learners were provided the opportunity to provide contact information if they wanted to continue participating in the qualitative interview portion of the research. The researcher reviewed the change in score from pre-test to post-test (DV11) for the participants providing contact information. From these, the researcher selected three individuals to interview for their user experience. One of the individuals gained a large amount of points (preferably going from a score of 0 in the pre-test to a score of 6). This individual was considered a high uptake (HU) learner. The second individual either did not gain any points and maintained a low score, or even lost points from pre-test to post-test. This individual was considered a low uptake (LU) learner. The third individual was someone who scored in the middle in both the pre-test and the post-test (about a score of 3 on each). This person was considered a middle uptake (MU) learner. The purpose of choosing these profiles of participants was to get a range of user experience.

Data Collection

Quantitative

A research protocol for the entire mixed-methods study was developed and ethically approved to allow the research activities to take place in September 2022 (see Appendix B for IRB documentation). At that time, the six teachers were provided instructions to direct their students to complete the prototype Teaching Cell. Each student was assigned a unique account, and was asked to log into the Teaching Cell and complete it. When all the students were done (by the end of September 2022), the data was obtained from the Teaching Cell in order to analyze the evaluation results and the other analytics described above.

The study was set up in such a way that the researchers established and assigned Teaching Cell accounts to teachers and their classes, but the Teaching Cell did not collect any personally-identifiable data. Therefore, use of the Teaching Cell in the quantitative part of the study was anonymous. However, at the end of the Teaching Cell, learners were asked if they wanted to identify themselves to participate in the qualitative portion of the study.

The recruitment for participation in the qualitative portion of the study took place as the last screen of the evaluation step. This screen explained that the researcher who developed the Teaching Cell wanted to interview several students who used the Teaching Cell so she could better understand their experience and how to improve it. If the student was interested in placing themselves on a list for potential recruitment for participation in the qualitative portion of the study, they were asked to provide their name and a phone number so they could be contacted if they were selected for further study participation. If they were not interested, they did not complete this form, and no identifying information was collected about them.

Qualitative

As described earlier, Teaching Cell participants who provided their contact information were considered for participation in the qualitative portion of the study. The researcher reviewed the list of individuals who were interested in being contacted for the study. Those who fit the criteria for HU, LU, and MU were separated from the rest of the individuals. The goal was to contact and recruit one individual each from HU, LU, and

MU to participate in the qualitative portion (total n = 3). Individuals selected were contacted, and a single-phase interview was set up over videoconference. The participant underwent consent, and the interview was audio recorded and transcribed. Appendix C lists the questions that were asked. They related to the learner's experience using the Teaching Cell, and how it could be improved.

Data Analysis Strategy

Quantitative

As described earlier, the Teaching Cell was assessed for its ability to induce eight different DLPs in the learners (see DVs in Table 13). A descriptive analysis was conducted on each DV described in Table 13 with respect to how the DLP was measured in a Teaching Cell. For each of the DLPs assessed through evaluation statements, the proportion of learners agreeing with the statement was analyzed. For the DLPs addressed through analytic measurements, the distribution of responses was assessed for evidence of the learners experiencing DLPs. Data were stored in Microsoft Excel, and analyzed in the open source R language (R Core Team, 2019).

As shown in Table 13, DV1 was a measurement of *active learning* and operationalized as the number of questions selected during the "ask questions" step. Learners who were actively engaged in learning took a positive learning approach, asked curiosity-related questions, had more critical thinking processes, and showed cognitive presence during the learning (Buchanan et al., 2016; Vaughan, 2010). Especially in Chinese culture, most students were passive learners who stayed quiet during the whole lesson (Xiao, 2021). Based on these multiple pieces of evidence, it was assumed that asking questions would reflect active learning behavior. As the learner had a maximum of

12 questions to choose from, potential values for DV1 ranged between 0 (no active learning) and 12 (highest level active learning). A one-sample Student's t-test (population value = 0) at a common level of significance ($\alpha = 0.05$) was conducted. The rejection of the null hypothesis would be evidence of *active learning* taking place.

Another indicator of *active learning*, DV2, was measured through the four "How realistic the problems were" items during the evaluation, identified in Table 12. Descriptive statistics were used to summarize the responses to these 5-point Likert-scale items and then were visualized in a Likert plot from the package *likert* in R to estimate if active learning took place. Higher scale values with the items would indicate higher levels of *active learning*.

DV3 was a measure of *learner context* and *engaged activities* and was operationalized as the number of times the learner clicked on a hot link during the guidance step in search of more information. As there was a total of three links, the potential values for DV3 ranged between 0 and 3. Descriptive statistics were used to summarize the number of learning contents chosen. The histogram was also used to evaluate whether or not there was *learner context* and *engaged activities*. Higher scores would indicate more context and engagement.

DV4 was a measure of *engaged learner* and *engaged activities*. DV4 was operationalized as the number of teaching elements the learner used. As there were three elements, DV4 had values ranging between 0 and 3. Descriptive statistics were used to summarize the number of learning elements chosen. The histogram was also used to visualize the results. Higher scores represented more *engaged learner* and *engaged activities*.

DV5, another indicator of *engaged learner* and *engaged activities*, was measured through three "How much they engaged with in the teaching cell" items during the evaluation, identified in Table 12. Responses to these 5-point Likert-scale items were visualized in a Likert plot. As with DV2, higher scale values with the items would indicate a higher level of *engaged learner*.

DV6 was a measure of *learner ownership* and *engaged activities*. DV6 was operationalized as the number of elements the learner engaged with during the exercise step. As there were a total of four available elements, potential values for DV6 ranged between 0 and 4. Descriptive statistics were used to summarize the number of exercise elements chosen. The results were visualized in a histogram as well. Higher scores would indicate more *learner ownership* and *engaged activities*.

DV7 was a second indicator of *learner ownership* and *engaged activities*. DV7 was measured through three "How responsible or self-directed they felt for their learning" items during the evaluation, identified in Table 12. Responses to these 5-point Likert-scale items were visualized in a Likert scale plot. Higher scale values with the items would indicate higher *learner ownership* and more *engaged activities*.

DV8 was a measure of level of *technology support* and addressed the degree to which the Teaching Cell supported learners' diverse device use. When learners accessed the teaching cell, they reported the type of device they used (e.g., smart phone, tablet, desktop, etc.). Descriptive statistics were used to summarize the number of devices types used. This data was then visualized in a bar chart and compared. The more devices from which learners connect, the higher the level of *technology support* indicated.

DV9 was the second indicator of *technology support* and was measured through three "How easy it was to use with their technology" items during the evaluation, identified in Table 12. As with DV2, DV5, and DV7, responses were visualized in a Likert plot. Higher scale values with the items would indicate more *technology support*.

DV10 was a measure of *intuitive design* and was measured through three "Navigability" items during the evaluation, identified in Table 12. As with DV2, DV5, DV7, and DV9, responses were visualized in a Likert plot. Higher scale values with the items would indicate a more *intuitive design*.

DV11 was a measure of *facilitative teaching practices*. DV11 was operationalized as the mean difference between the pre-test and the post-test scores. Each test score ranged between 0 and 5. A paired sample t-test was planned to compare the means of pre-test and post-test scores. A statistically significant positive difference would indicate the existence of *facilitative teaching practices*.

Qualitative

After transcription, the data from the interviews underwent thematic analysis as detailed in Burnard et al. (2008). Briefly, each of the three interviews was first translated into English (see Appendix D for transcriptions). Next, transcriptions from each interview were coded into initial coding frameworks. An initial coding framework was where each statement from the interview by the participant was isolated, and thematic codes were applied. Each participant had their own initial coding framework (Burnard et al., 2008). This system of themes created as the initial coding frameworks were developed was updated each time another initial coding framework was created, thus creating inductive themes (Burnard et al., 2008).

These initial coding frameworks were reassembled into a final coding framework for presenting hierarchical themes and subthemes (Burnard et al., 2008). This were presented in a tabular format and were described using quotes from actual participants (Burnard et al., 2008).

Chapter 4

Results

In an effort to examine the potential of adaptive microlearning to improve deeper learning among public school students in rural China, this study implemented and used a innovative adaptive microlearning prototype (Teaching Cell) as a supplement to formal face-to-face classroom instruction. The chapter is organized beginning with a description of the sample, followed by the findings from both quantitative and qualitative data analyses. The chapter ends with a summary synthesizing the findings from both quantitative and qualitative data.

Description of the Sample

Participants of the study were eighth grade students at the Chang'an District Middle School, Shaanxi province, China during September 2022. In total, 183 students from eighth grade (three classes) in this school had the opportunity to participate in the study, of which 145 (79.23%) completed their participation. Table 14 provides the demographics.

Table 14

Breakdown of Study Participants

Category	Level	n	Percent
All	All	145	100
Gender	Female	67	46
	Male	65	45
	Did not want to say	13	9
Age in years	11	1	1
	12	0	0
	13	131	90
	Not reported	10	7
Teaching Cell completion	Step 2 (Ask Questions)	49	34
	Step 3 (Guidance) and Step 4 (Teaching)	49	34
	Step 5 (Exercise)	43	30
	Step 1 (Pretest) and Step 6 (Post-test)	20	14
	Step 7 (Evaluation)	26	18

According to Table 14, participants were split evenly by gender, and most of the students (90%) were age 13. However, due to technical problems with the Teaching Cell, not all the data was recorded from the learners. For Steps 2, 3, and 4, only 49 students provided data that could be analyzed. For Step 5, only 43 students had adequate data, because it there was enough not missing so that it could be analyzed, and for Step 7, only 26 students supplied adequate data. To look at changes between pre-test and post-test, students needed to have completed Steps 1 and Step 6, and only 20 records met those criteria.

Findings from the Quantitative Data

Research Question 1: Active Learning

The DLP of Active Learning was assessed at two different data points in Teaching Cell (Steps 2 and 7). The data collected during Step 2: Ask Questions (the number of questions the learner chose) was used to analyze the following hypotheses:

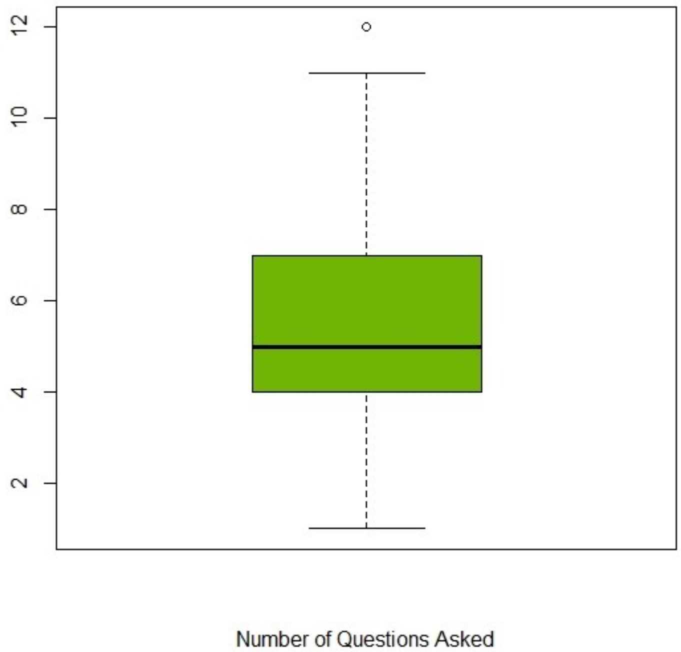
$H_0 1$: The mean number of questions participants ask ($\mu 0$) is equal to the population mean ($\mu = 0$).

$H_A 1$: The mean number of questions participants ask ($\mu 0$) is higher than the population mean ($\mu > 0$).

Data from 49 Teaching Cell records were available for this analysis (see Table 14), and the learners had 12 questions to choose from (possible score range: 0 and 12). The mean score was 5.8, and the median score was 5. This variable is visualized in a box plot in Figure 25. The variable appeared normally distributed. As one-sample t-test ($t = 13.2$, $df = 48$, $p < 0.0001$) showed statistical significance, the null hypothesis was rejected. The results suggest that the learners were engaged in Active Learning in Step 2: Ask Questions.

Figure 25

Box Plot Distribution of Number of Questions asked in Step 2

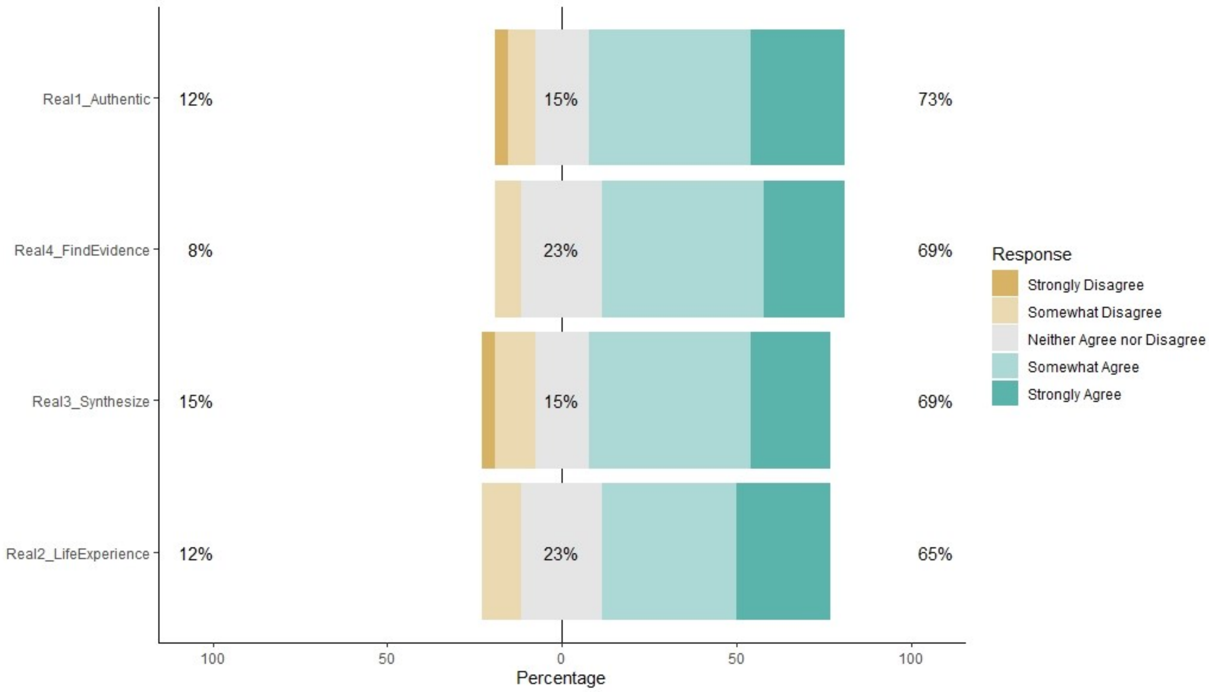


The data collected during Step 7: Evaluation was how realistic the problems were in the Teaching Cell. There were four self-report items relevant to Active Learning: 1) The learning materials in the Teaching Cell are authentic to me (*Real1_Authentic*), 2) The learning result from the Teaching Cell could relate to my real life experiences (*Real2_LifeExperience), 3)* I learned realistic ways to synthesize and think during Teaching Cell learning (*Real3_Synthesize*), and 4) I learned how to find evidence for the accuracy of the learning contents (*Real4_FindEvidence*).

Since these were assessed in the Evaluation Step, only 26 records were available for analysis (see Table 14). The overall total agreement was high on each item, ranging from 65% to 73%. Figure 26 presents the distribution of responses on these four items. Although there is no statistical test, this descriptive analysis suggests that there is compelling evidence that the learners felt that the Teaching Cell items were realistic, and this related to their active learning.

Figure 26

Distribution of Responses on Evaluation Items Associated with Level of Realism Reported



Note. Each horizontal bar represents an item; the items are labeled with the codes presented along the left side of the y-axis. Each bar has a center area that is grey; this indicates the proportion of answers of three, which represents "neither agree nor disagree", and is labeled with the percentage of responses in that category. To the right side of the grey area is a light green section representing the number of responses of four, meaning "somewhat agree", and the dark green section representing the number of responses of five, meaning "strongly agree". The percentage listed along the y-axis on the right indicates the percentage of responses of either four or five (percentage agreement overall). To the left of the grey area on each bar is a light gold section representing responses of two (indicating "somewhat disagree") and a dark gold section representing responses of one (indicating "strongly disagree"). The percentage listed along the left y-axis is the percentage of responses of one and two together to each item (percentage disagreement overall). In the figure, the items are ordered starting with the highest total agreement.

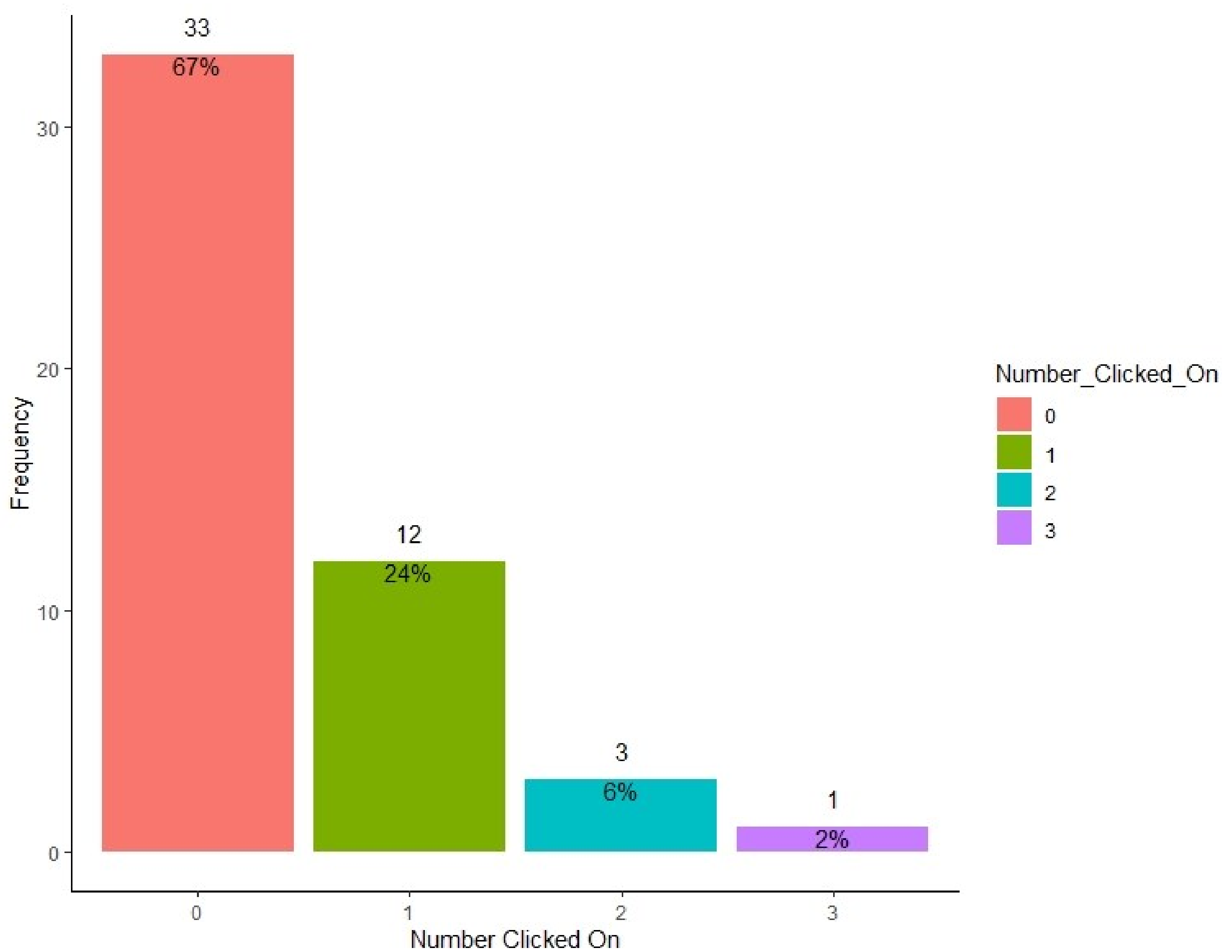
Research Question 2: Learner Context

The DLP of Learner Context was assessed during Step 3: Guidance. This step had three hot spots that learners could click on to guide them about the context of the information they were going to learn in the Teaching Cell. Learners could click on none of the hot spots, one of them, two of them, or all three of them. The assumption was that the more hot spots on which they clicked, the more Learner Content and Engaged Activities was taking place. As described in Table 14, 49 records were included in this analysis due to having complete data.

The data collected during Step 3: Guidance (the number of hot spots on which the learner clicked) were analyzed by descriptive statistics which showed that over two-thirds (67%) of the learners did not click on any of the guidance hot spots. Figure 27 presents the distribution of hot spots clicked. Although no statistical tests could be used, this descriptive analysis suggests that the guidance step did not support Learner Context.

Figure 27

Distribution of Hot Spots Clicked in Guidance Step



Research Question 3: Engaged Learner

The DLP of Engaged Learner was assessed using data from two different steps in the Teaching Cell (Steps 4 and 7). In Step 4: Teaching of the Teaching Cell, items were completed indicating learners' intention to engage with the teaching elements. There were three teaching elements: a video, a PowerPoint slide presentation, and an audiobook. Learners were asked in the Teaching Cell to check off which elements they were interested in using to study the lesson – the video, PowerPoint, and/or audiobook – or to skip all of the teaching elements. As described in Table 14, 49 records were included in this analysis.

The descriptive statistics uncovered that PowerPoint was the most popular, in that more than half (51%) selected it, with 43% selecting video and 27% selecting audiobook. Figure 28 shows the frequencies of the types of teaching elements the learners were interested in using. Overall, only 22% of the learners indicated they intended to skip all the teaching elements, while over half of them (51%) indicated that they would use one of the teaching elements, and 16% indicated they planned to use all three. Figure 29 shows the overall frequency of teaching elements selected. Although descriptive in nature, these findings provide strong evidence that the teaching elements lead to an Engaged Learner.

Figure 28

Frequency of Type of Teaching Elements Selected

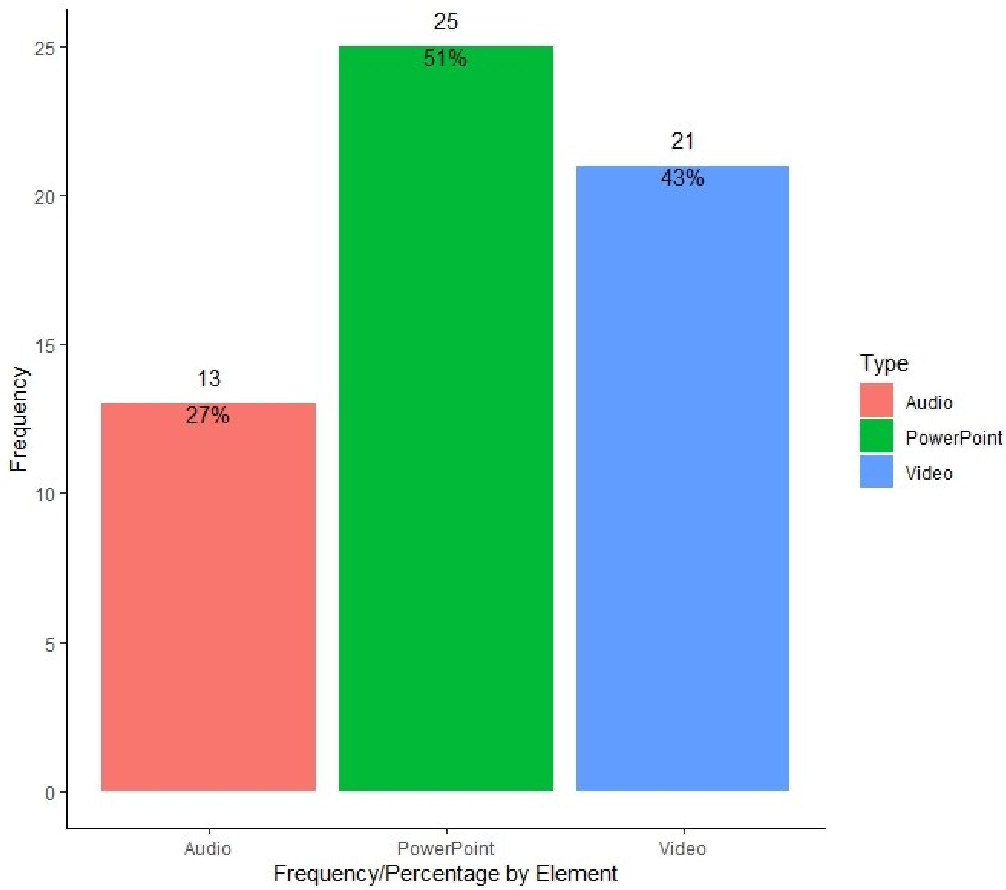
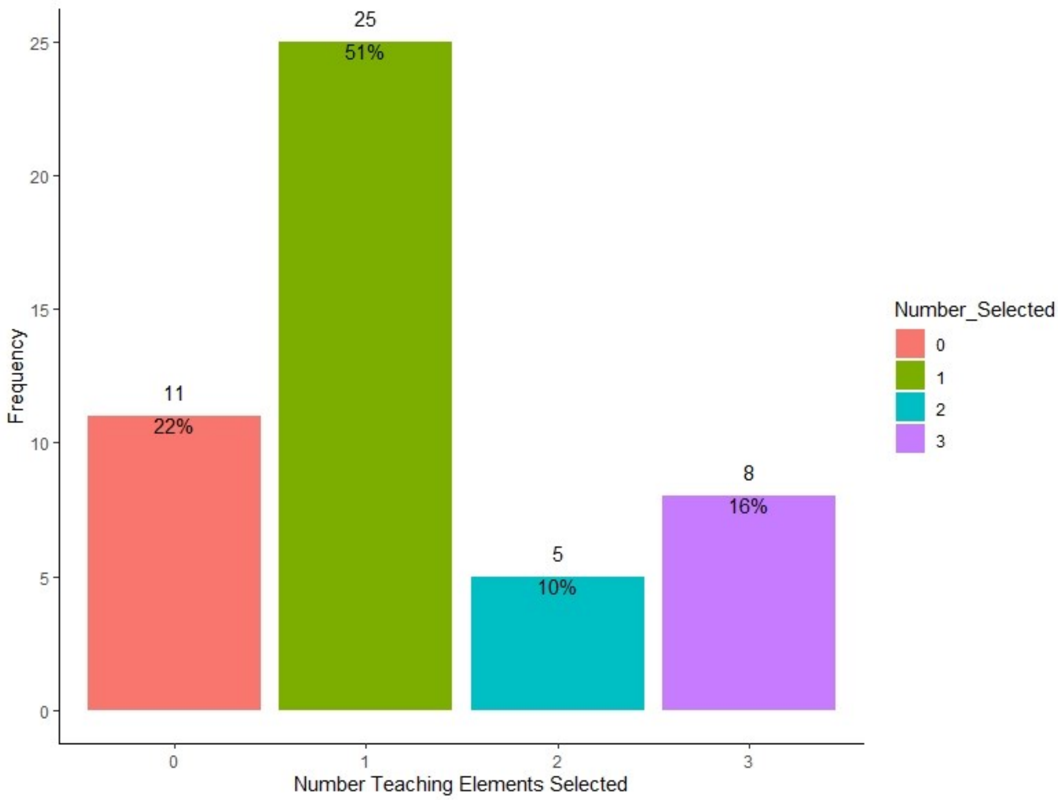


Figure 29

Overall Frequency of Teaching Elements Selected

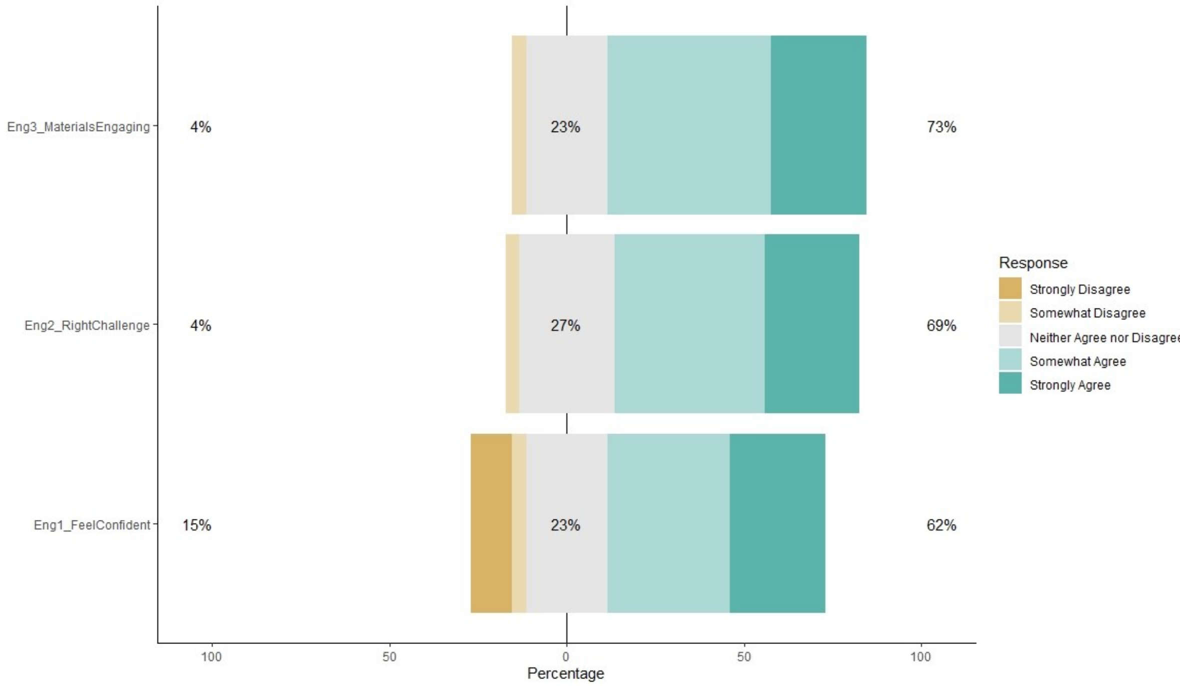


The DLP of Engaged Learner was also assessed during Step 7: Evaluation via three self-report items (n = 26): 1) I felt confident when I did the test after learning using the Teaching Cell (*Eng1_FeelConfident*), 2) I feel the Teaching Cell's learning materials are at the right level of challenge for me (*Eng2_RightChallenge*), and 3) I feel learning materials in the Teaching Cell are very engaging (*Eng3_MaterialEngaging*).

The descriptive statistics revealed that overall agreement was 62% for feel confident after learn, 69% for right level of challenge and 73% for engaging materials (see Figure 30). It is important to note the large number of those who felt neutral, which was approximately one-fourth of the participants (23% for two items and 27% for the other). This descriptive analysis provides some support for the claim that the Teaching Cell was associated with the DLPs of Engaged Learner.

Figure 30

Distribution of Responses on Evaluation Items Associated with Attitudes Toward Engagement



Research Question 4: Learner Ownership

The DLP of Learner ownership was assessed using data from two steps in the Teaching Cell (Step 5 and Step 7). During Step 5: Exercise, learners were asked to indicate which of four exercise activities they were interested in: a Jeopardy-inspired trivia game about the learning material ("Jeopardy game"), a link game with concepts to match the learning material ("link game"), flashcards, or a discussion board (n = 43). Participants could select one, two, three, four, or none depending on their interests. The assumption was that the more they select, the more they take Learner Ownership.

Each of the four exercise items was interesting to approximately one-third of the participants. For the discussion board, Jeopardy game, and link game, 15 participants each (35%) indicated they were interested in using those exercises, while 13 (30%) said they were interested in the flash cards. See Figure 31 for the type of exercise elements selected. When considered overall, approximately one-fourth of the participants (26%) indicated that they would skip the exercise step. In terms of engagement, over one-fourth (28%) said they would use two or more exercise elements, and almost half (47%) said they intended to use only one. Figure 32 summarizes the distribution of all exercise elements selected. These findings suggests that there may have been evidence of Learner Ownership. From this descriptive analysis, it seems there is weak evidence that the Exercise step induced the DLPs of Learner Ownership.

Figure 31

Frequency of Type of Exercise Elements Selected

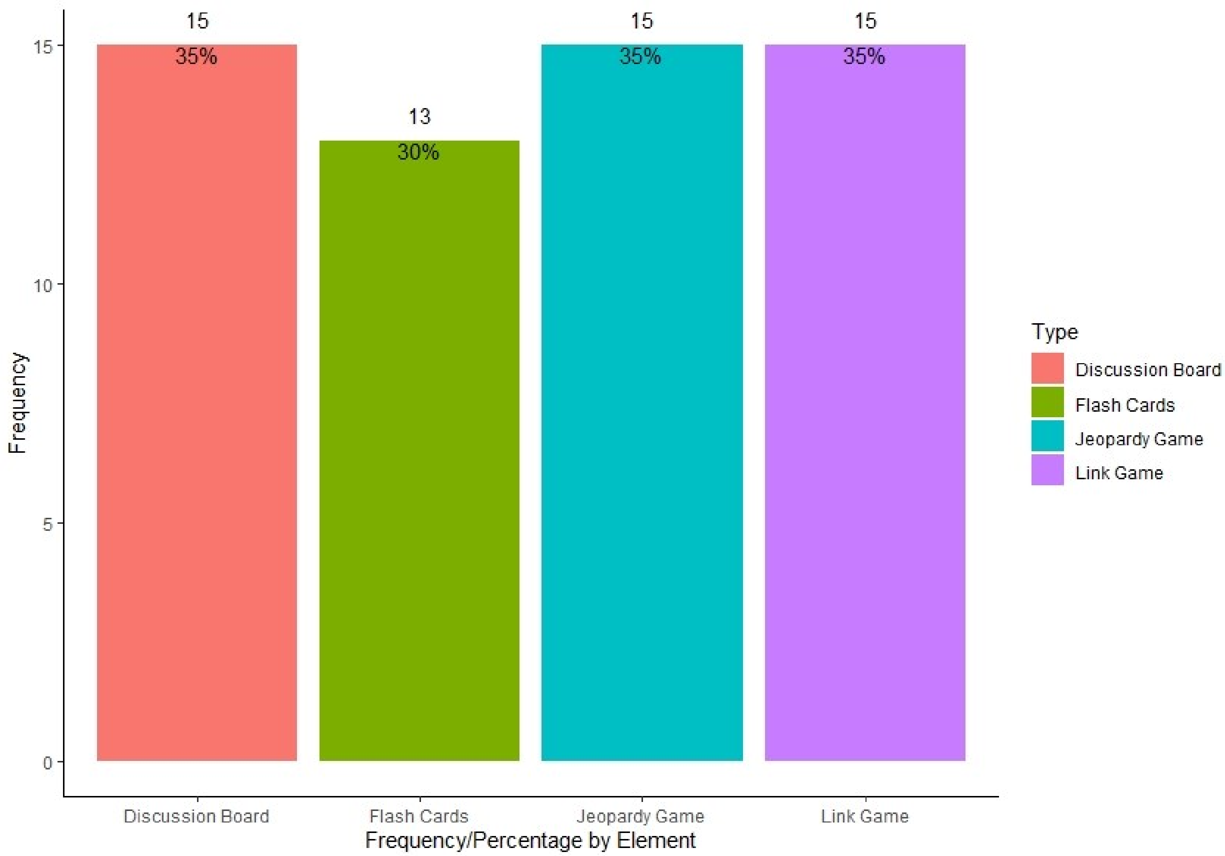
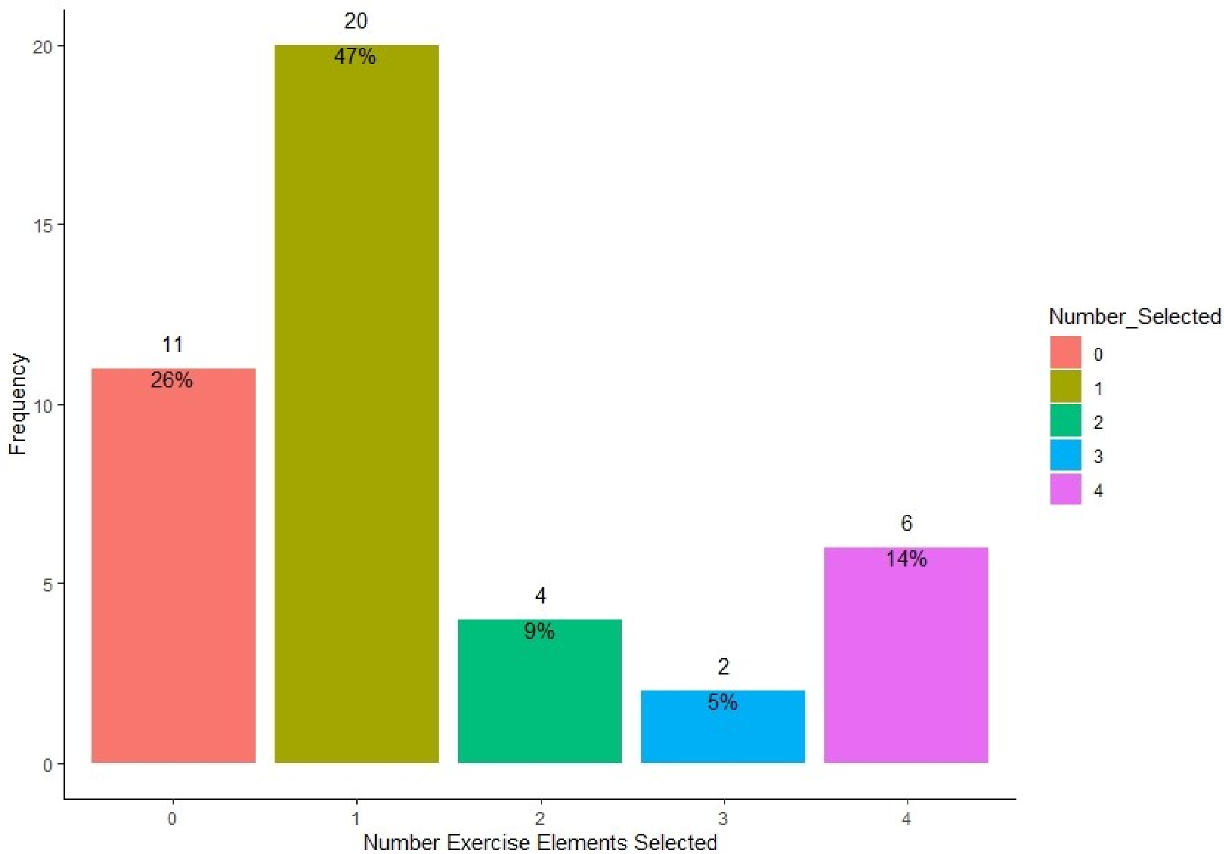


Figure 32

Overall Frequency of Exercise Elements Selected

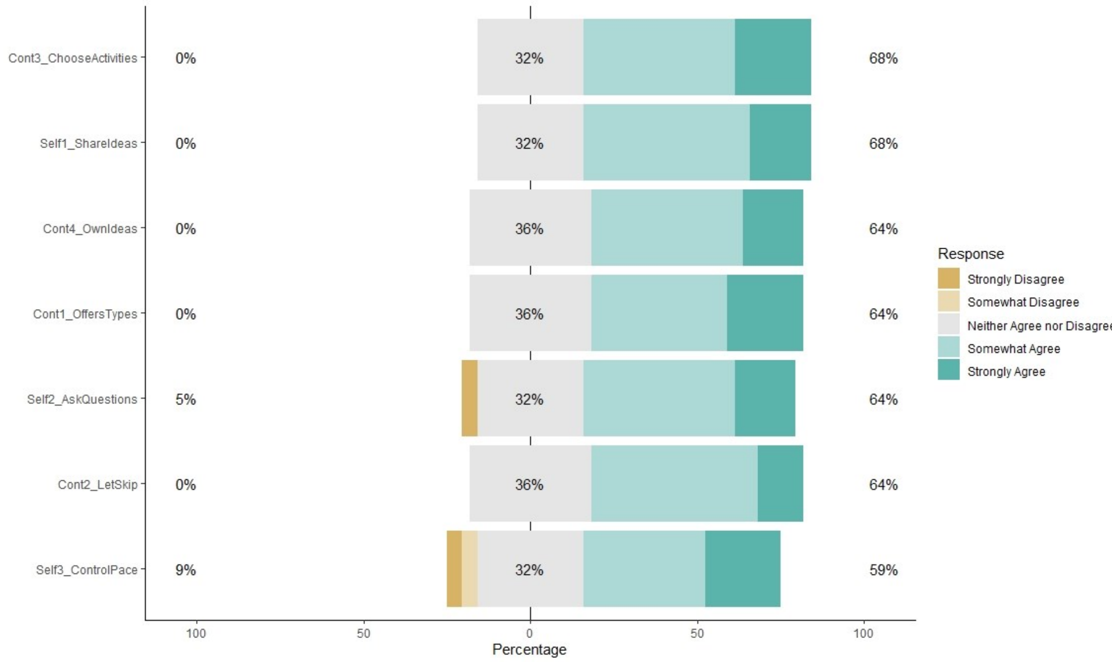


The DLP of Learner Ownership was once again assessed during Step 7: Evaluation, through seven self-report items: 1) I feel encouraged to share my ideas in the Teaching Cell (*Self1_ShareIdeas*), 2) I feel encouraged to ask questions in the Teaching Cell (*Self2_AskQuestions), 3)* I feel the Teaching Cell allows me to control the pace of my learning without any pressure (*Self3_ControlPace*), 4) The Teaching Cell offers me ways to learn using different types learning materials (*Cont1_OffersTypes*), 5) The Teaching Cell let me skip what I already knew to save my learning time (*Cont2_LetSkip*), 6) The Teaching Cell allows me to choose the learning activities that interest me to make learning more fun (*Cont3_ChooseActivities*), and 7) I could add my own ideas into the Teaching Cell (*Cont4_OwnIdeas*). Due to missing data on some of these items, only 22 records were retained for this analysis.

The descriptive statistics showed that learners were reluctant to disagree with any of the items, as summarized in Figure 33. Almost one-third indicated they were neutral on each item (27% to 36%). Yet, there was a high rate of overall agreement, ranging from 59% to 68%. These findings provided evidence that the Teaching Cell supports Learner Ownership.

Figure 33

Distribution of Responses on Evaluation Items Associated with Learner Ownership



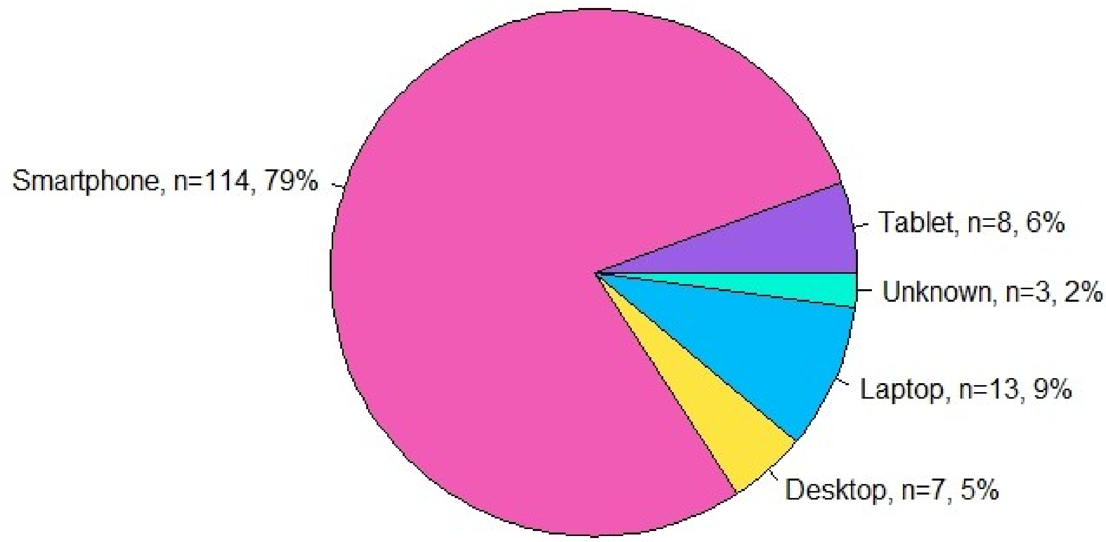
Research Question 5: Technology-supported Learning

The DLP of Technology-supported Learning was assessed in two ways. In the first approach, learners were asked what type of device they used to connect to the Teaching Cell. In order for the Teaching Cell to support technology (consistent with DLPs), learners should be able to connect and use the Teaching Cell from whatever device they choose, and the Teaching Cell should be able to support connections from multiple device types.

The descriptive statistics revealed that while more than three-fourths (79%) used their smartphones, the Teaching Cell also supported learners using a laptop (9%), tablet (6%), and desktop (5%). Even though there was a predominance in the use of one type of device, there was still evidence that the Teaching Cell supported connections from other devices, demonstrating that the Teaching Cell could support a diversity of device access. These results provide evidence that the Teaching Cell was technology-supported. Figure 34 shows the distribution of device types that learners reported (n = 145).

Figure 34

Distribution of Type of Technology Used to Connect to Teaching Cell

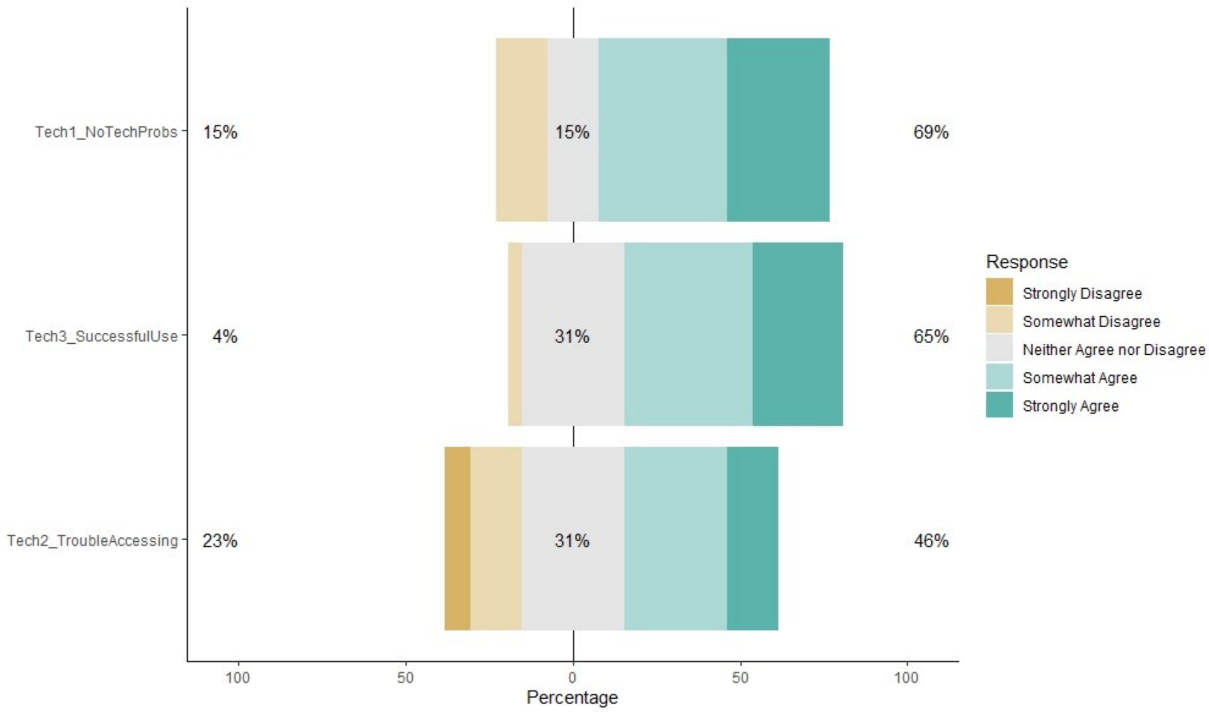


Whether the Teaching Cell was supportive of technology (consistent with DLPs) was also assessed during Step 7: Evaluation via three self-report items (n = 26): 1) I had no technological problems using the Teaching Cell with my technology (*Tech1_NoTechProbs*), 2) I had trouble accessing the Teaching Cell (*Tech2_TroubleAccessing*), and 3) I was successful using the Teaching Cell on different technology tools (Laptop, iPad, Smartphone) (*Tech3_SuccessfulUse*).

The distribution of responses on these three items, summarized in Figure 35, provides evidence that there were technological issues with the Teaching Cell, in that 15% disagreed with the statement that they had "no technical problems" with the Teaching Cell, and 46% reported having trouble accessing the Teaching Cell. This descriptive analysis provides evidence that the Teaching Cell was not technology-supported.

Figure 35

Distribution of Responses on Evaluation Items Associated with Ease of Technology Use



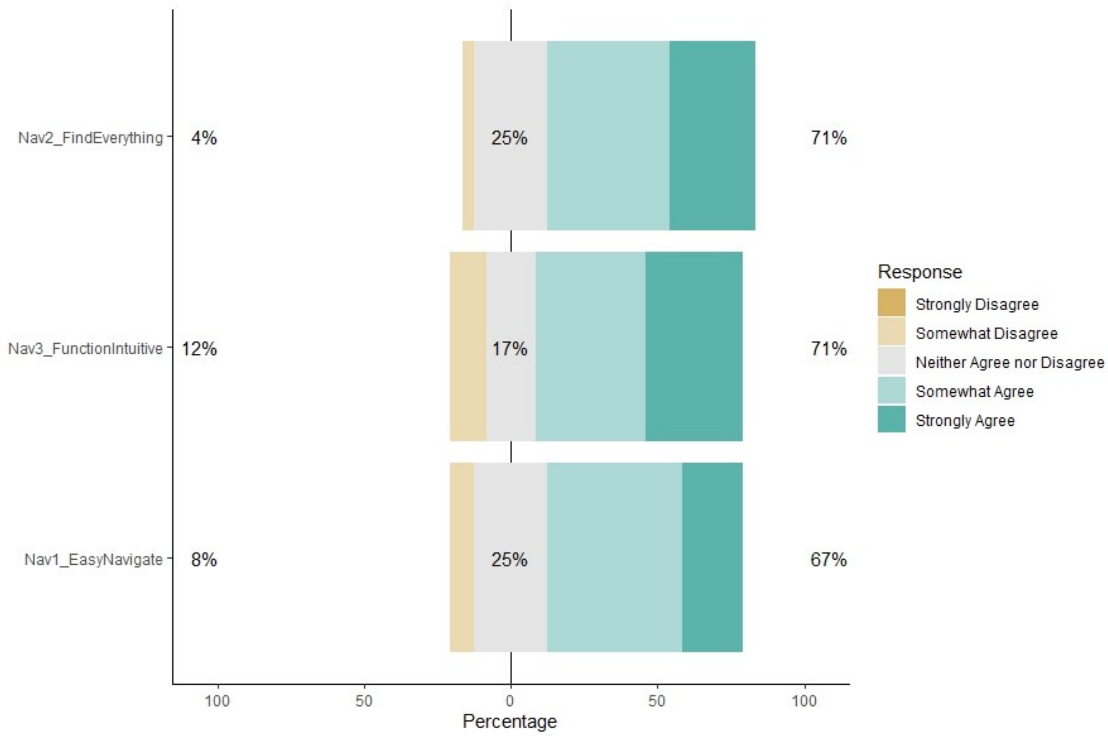
Research Question 6: Intuitive Design

The DLP of Intuitive Design was assessed during Step 7: Evaluation via three self-report items about navigability in the Evaluation step (n = 24): 1) The Teaching Cell was easy to navigate (*Nav1_EasyNavigate*), 2) I was able to find everything I was looking for in the Teaching Cell (*Nav2_FindEverything*), and 3) The function of the different items in the Teaching Cell was intuitive (*Nav3_FunctionIntuitive*).

The findings from the descriptive statistics showed that although 71% agreed that the navigation was intuitive and they could find everything, 4% disagreed that they could find everything, and 12% disagreed that the functions were intuitive. Further, while 67% agreed the Teaching Cell was easy to navigate, 8% disagreed. The distribution of responses on these items is visualized in Figure 36. The navigation was intuitive to a large percentage, but not all the learners, so even though learner response was overall positive, this is an area where there could be a future improvement.

Figure 36

Distribution of Responses on Evaluation Items Associated with Intuitive Design and Ease of Navigability



Research Question 7: Engaged Activities

The DLP of Engaged Activities was assessed using data from multiple steps throughout the Teaching Cell: Step 3: Guidance (same as in Research Question 2), Step 4: Teaching (same as in Research Question 3), Step 5: Exercise (same as in Research Question 4), and Step 7: Evaluation (same as in Research Questions 3 and 4). As can be seen in Figure 27, that over two thirds (67%) of the learners did not click on any of the guidance hot spots. Although no statistical tests can be used, this descriptive analysis suggests that the guidance step did not support Engaged Activities. As shown in Figure 29, over half of participants (51%) indicated that they would use one of the teaching elements, and 16% indicated they planned to use all three. Although this is a descriptive analysis, this provides strong evidence that the teaching elements lead to Engaged Activities. As shown in Figure 30, responses on the evaluation items indicated learners felt they were engaging with the activities of the Teaching Cell. As shown in Figure 32, learners selected many different exercise elements, indicating Engaged Activities. Finally, through prevalent agreement on items in the evaluation associated with Engaged Activities as shown in Figure 33, learners expressed that they were engaged with the activities of the Teaching Cell.

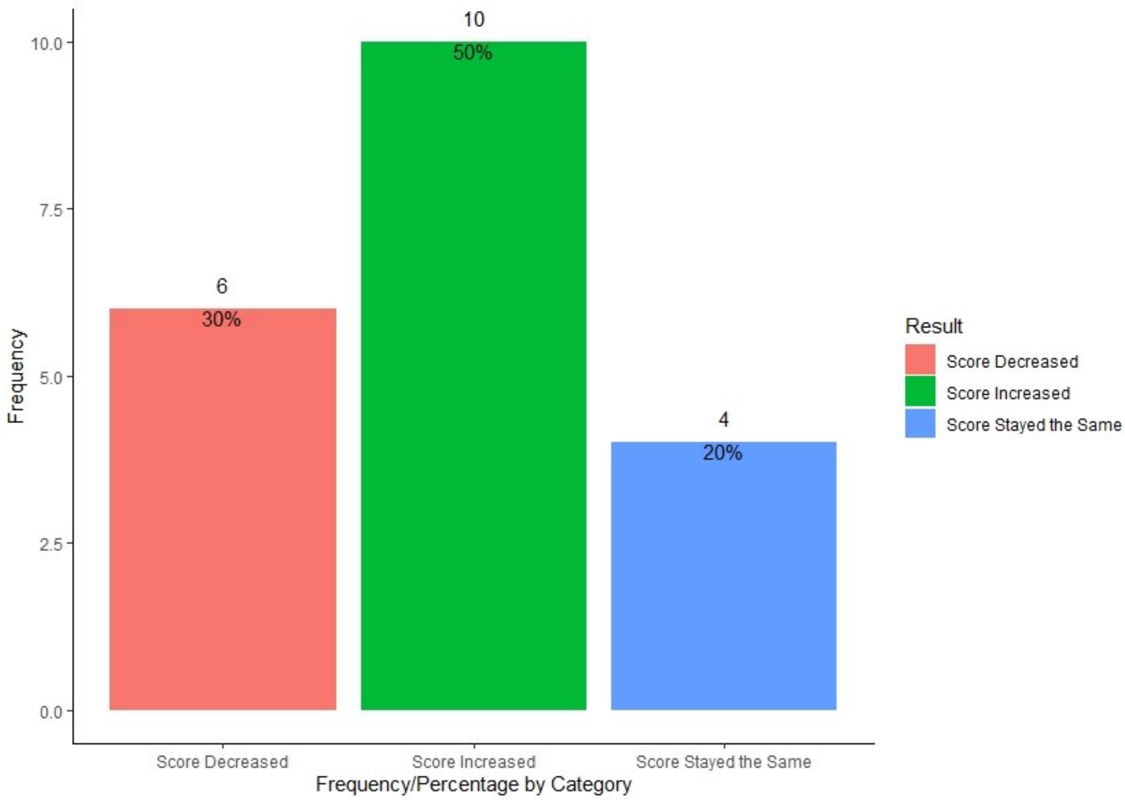
Research Question 8: Facilitative Learning Practices

The assessment of Facilitative Teaching Practices was constructed by taking the post-test score from Step 6 and subtracting from it the pre-test score from Step 1. Each was a multiple-choice test with five questions, so the learner could get a score between zero and five. The assumption was that in the pre-test, learners would have a low score, and after going through the Teaching Cell, they would have more knowledge leading to a higher score on the post-test. If the Teaching Cell included Facilitative Teaching Practices, then learners would increase their score from the pre-test to the post-test, and subtracting the pre-test from the post-test score would have a positive result. This score difference was calculated; originally, a paired t-test had been planned, but due to small sample, a descriptive analysis was used instead. The calculated differences were classified into three groups: scores that decreased from Pre-test to Post-test, scores that stayed identical from Pre-test to Post-test, and scores that increased from Pre-test to Post-test (n = 20). These are graphed in Figure 37.

As can be seen in Figure 37, exactly half (50%) of the learners saw their score increase between the Pre-test and the Post-test. However, for 20%, the score stayed the same, and it decreased by 30%. Therefore, in this small sample, the Teaching Cell did not appear to align with Facilitative Teaching Practices for all learners, although it appeared to increase knowledge in a subset of learners.

Figure 37

Distribution of Differences in Scores from Pre-test to Post-test



Findings from the Qualitative Data

Three participants were chosen for in-depth interviews among the participants who indicated their willingness to participate in the interview (in both the parent permission form and the child assent form which are included in Appendix B) and completed the Teaching Cell. These three students were chosen based on their willingness to be interviewed and the data reflecting their use of the Teaching Cell. The first selected interviewee (S1) performed at an outstanding level, in that they engaged in every activity, and provided many positive responses in evaluation section. The second selected interviewee (S2) performed fairly on the Teaching Cell activities, but skipped other activities. This individual also left some positive responses in evaluation section. The final selected interviewee (S3) skipped the Guidance section (which most participants skipped), and had a diversity of responses in the evaluation section suggesting that they had contradictory opinions and thoughts.

This section will summarize the qualitative evidence of Teaching Cell DLPs found in the interview responses from the three interviewees (S1, S2, and S3, transcripts in Appendix D).

Research Questions 1 and 7 (Active Learning and Engaged Activities)

All three interviewees provided evidence supporting both the active learning and the engaged activities DLPs when describing their experience with the Teaching Cell. As stated before, the active learning DLP includes solving real-world problems, and the engaged activities DLP involves being able to make a unique contribution to learning (Wickersham & McGee, 2008).

Overall, the interviewees liked the Teaching Cell and had mostly a positive attitude toward using it. All of the interviewees expressed that they had a good experience using the Teaching Cell, and they felt actively engaged in learning:

> *S1: I think the most impressive part is the Guidance. It made me feel very clear about what I needed to learn in the whole picture.*
>
> *S2: My favorite parts are the fun exercises. These are very interesting!*
>
> *S3: [The Teaching Cell is] fun and short. It has many extracurricular activities.*

Two of the interviewees compared the Teaching Cell to other apps:

> *S2: Most of our learning apps offer the same content, just different stages or lessons.*
>
> *S3: We are always asked to finish everything on other platforms, which sometimes makes me very bored, and it's time-consuming.*

It seems that the Teaching Cell excelled compared to other learning apps because it allowed learners to be engaged and active with its content rather than forcing them to go through a fixed learning path with non-interactive content. Overall, all three interviewees expressed that they were actively interacting with the Teaching Cell and that they became engaged with the Teaching Cell.

Research Questions 2, 3, and 4 (Learner Context, Engaged Learner, and Learner Ownership)

Interviewees provided evidence supporting the DLPs of learner context, engaged learner, and learner ownership when reflecting upon their Teaching Cell experience. The learner context DLP includes being able to choose what to learn, the engaged learner DLP relates to the learner choosing specific learning pathways, and the learner ownership DLP includes the ability to set goals and timelines (Wickersham & McGee, 2008).

One of the strongest DLPs expressed by interviewees was learner context. Interviewees explained how the intelligent aspect of the Teaching Cell was attractive because it fit into their context and helped them choose among viable learning choices:

> *S1: The Teaching Cell will target my learning based on my interests. It's very nice.*
>
> *S2: It's very intelligent and could help me focus on my own learning strengths and weaknesses. … Teaching Cell is very personalized. … So the Teaching Cell could make more targeted learning for us to make learning easier.*

Learners also expressed satisfaction and engagement with the fact that they could determine their own learning pathways in the Teaching Cell:

> *S2: [With the Teaching Cell] I feel I could find a better and more suitable learning method for my learning, and it can help me learn better in the classroom, too.*
>
> *S3: My favorite part is I can choose from everything. I can choose what to learn, and I have a chance to skip.*

These features of the Teaching Cell made it easier for the interviewees to take ownership of their learning and set goals and timelines. They all expressed this sentiment in their own way:

S1: I think the Teaching Cell is very useful for preview and review.

S2: It may help me from the preview to the review of the lessons.

S3: The Teaching Cell allows me to do a short lesson, but it's very useful because it's personalized. Saved me a lot of time.

In summary, this qualitative evidence suggests that the Teaching Cell was consistent with the DLPs of learner context, engaged learner, and learner ownership.

Research Questions 5 and 6 (Technology Supported and Intuitive Design)

The technology-supported DLP includes having learners access the learning using various technological means, and intuitive design relates to the ability to navigate and understand how to use the features of the Teaching Cell (Wickersham & McGee, 2008). Interviewees reported challenges in navigating the Teaching Cell and connectivity issues during the Teaching Cell sessions. Here are some quotes from interviewees that shed light on these DLPs:

S1: The whole process is a little bit confusing, in that sometimes, I don't know which button I should use.

S3: The Teaching Cell is very new to me. I never tried learning platforms like this. … Sometimes I don't know what to do with this new platform. The layout and design are not familiar to me.

These responses made it clear that the Teaching Cell prototype, built in Qualtrics, was not well-supported by the technologies the learners used and did not offer intuitive design. Interviewees were confused about how to navigate the Teaching Cell. It is, however, not clear if this is because the Qualtrics design was suboptimal, or if the Teaching Cell was not displaying correctly on their technological devices.

Research Question 8 (Facilitative Learning Practices)

The DLP of facilitative learning practices includes how much learning and retention took place in the learner due to the deeper learning experience (Wickersham & McGee, 2008). Interviewees provided contradictory evidence to the findings from the quantitative data analysis regarding the DLP of facilitative learning practices. That is, while the findings of the quantitative data showed limited improvement in their learning, interviewees reported otherwise:

> *S1: I think the Teaching Cell has more logical frames that could help me make a better connection among the knowledge [in the app]. ... We would like to learn more related knowledge besides the textbook. The Teaching Cell provided much-related knowledge [like an] extra curriculum, and I found much knowledge that interested me, that was never shown in the textbook.*
>
> *S2: My overall experience is I feel improvement in my logical and cognitive capabilities by using the Teaching Cell. ... Another part I liked is the content of Teaching Cell because it extends the knowledge, which helps me learn more than the textbook and is more fun!*
>
> *S3: I think everything [about the Teaching Cell] is new compared to other apps. Totally personalized with contents, tests, and also steps. And very short lessons. Different students get different experiences. We discussed this after we did the survey.*

On the one hand, these comments could suggest that simply measuring factual knowledge in a multiple-choice test like the pre-test and post-test did not measure the actual deeper learning that took place. On the other hand, interviewees might have altered their responses as they were aware of being observed (Hawthorn effect). Nonetheless, as the quantitative and qualitative findings contradict each other, consideration should be given to different approaches to learning assessment.

Summary of Findings

The quantitative data analysis findings showed that the Teaching Cell fulfilled many DLPs. For example, there was evidence supporting the DLPs of active learning, engaged learner, learner ownership, and engaged activities. Mixed evidence was also found for the DLPs of technology-supported, intuitive design, and facilitative teaching practices. However, there was a lack of evidence supporting the learner context DLP. Table 15 provides a summary of findings from quantitative data analyses.

Table 15

Summary of Quantitative Data Analysis Results

Type of Deeper Learning	What Was Measured	Long Interpretation	Short Interpretation
Active Learning	Number of questions selected in Ask Questions step (DV1)	Using a statistical test, the null was rejected ($p < 0.0001$). The learners were statistically significantly engaged in active learning in the Ask Questions step.	+++
	Four items on the Evaluation step asking about the level of realism of the learning contents (DV2)	There was between 65% to 73% agreement with the items, so from a descriptive analysis, it appears they were engaging in active learning.	++
Learner Context	Number of hot spots clicked on the Guidance step (DV3)	Because 67% did not click on any hot spots, descriptive analysis suggests that the guidance step did not support the learner context principle.	--
Engaged Learner	Number of teaching elements selected for intended use on the Teaching step (DV4)	Only 22% indicated they were not interested in using any of the teaching elements. Over half (51%) intended to use one of them, and 16% intended to use all three of them.	++
	Three items on the Evaluation step asking about attitudes toward engagement with the teaching cell (DV5)	Overall agreement was 62-73%, but approximately one fourth indicated they neither agreed nor disagreed with the items.	+

Table 15 (continued).

Type of Deeper Learning	What Was Measured	Long Interpretation	Short Interpretation
Learner Ownership	Number of exercise elements selected for intended use on the Exercise step (DV6)	Over one fourth (26%) said they did not intend to use any exercise elements, and a little over another fourth (28%) indicated they would do two or more of the exercises, indicating weak evidence of learner ownership.	+
	Seven items on the Evaluation step asking the learner how much control they felt they had over their learning experience and in what activities they engaged (DV7)	Learners were reluctant to disagree with any items, and about one third answered "neutral" for each item. There was a high rate of overall agreement (59% to 68%), so there is weak evidence supporting learner ownership.	+
Technology-supported	Learners were asked to report the type of device they were using to connect to the Teaching Cell (DV8)	More than three-fourths (79%) connected using their smartphones, with others connecting with laptop (9%), tablet (6%) and desktop (5%). This provides evidence the Teaching Cell was technology-supported.	+
	Three items on the Evaluation step asking about learner's experience with the technology in the Teaching Cell (DV9)	Fifteen percent disagreed with the statement that they had “no technical problems” with the Teaching Cell, and 46% reported having trouble accessing it.	--
Intuitive Design	Three items on the Evaluation step asking about learner's ease of navigability (DV10)	Although 71% agreed that the navigation was intuitive and they could find everything, 4% disagreed that they could find everything, and 12% disagreed that the functions were intuitive	+

Table 15 (continued).

Type of Deeper Learning	What Was Measured	Long Interpretation	Short Interpretation
Engaged Activities	Number of hot spots clicked on the Guidance step (DV3)	Because 67% did not click on any hot spots, descriptive analysis suggests that the guidance step did not support the engaged activities principle.	--
	Number of teaching elements selected for intended use on the Teaching step (DV4)	Only 22% indicated they were not interested in using any of the teaching elements. Over half (51%) intended to use one of them, and 16% intended to use all three of them.	++
	Two items on the Evaluation step asking about attitudes toward engagement with the teaching cell (DV5)	Overall agreement was 62-69%, but approximately one fourth indicated they neither agreed nor disagreed with the items.	+
	Number of exercise elements selected for intended use on the Exercise step (DV6)	Over one fourth (26%) said they did not intend to use any exercise elements, and a little over another fourth (28%) indicated they would do two or more of the exercises, indicating weak evidence of engagement.	+
	Eight items on the Evaluation step asking the learner how much control they felt they had over their learning experience and in what activities they engaged (DV7)	Learners were reluctant to disagree with any items, and about one third answered "neutral" for each item. There was a high rate of overall agreement (59% to 68%), so there is weak evidence supporting engaged activities.	+

Table 15 (continued).

Type of Deeper Learning	What Was Measured	Long Interpretation	Short Interpretation
Facilitative Teaching Practices	Difference in score between the Pre-test and the Post-test (DV11)	Exactly half (50%) of the learners saw their score increase between the Pre-test and the Post-test, but for 20%, the score stayed the same, and it decreased in 30%, so the teaching practices were not facilitative for all learners.	+/-

The findings from qualitative data were similar to the ones from quantitative data, offering supporting evidence for the DLPs of active learning and engaged activities. As for the DLPs for learner ownership, learner context, and engaged learner, however, qualitative data provided better insight into how learner ownership, learner context, and learner engagement took place in the Teaching Cell. Every interviewee echoed the sentiment that they loved the way they could determine their own learning pathways in the Teaching Cell, use it for preview and review, enter and exit it whenever they wanted, and skip sections, so they are not forced to use parts of it they do not want to use.

The quantitative data findings did not offer supporting evidence for the DLPs of technology-supported and intuitive design, in line with the results from quantitative data, suggesting the need for improvement in the Teaching Cell. As for facilitative teaching practices, quantitative and qualitative findings contradicted each other. These discrepant results suggest that the assessment of learning needs to be revised.

Overall, there was evidence that the Teaching Cell successfully supported five of the eight DLPs. Improvement is needed for Teaching Cell to embrace the technology-supported DLP and the intuitive design DLP. The Teaching Cell also needs to improve facilitative teaching practices and student learning assessment.

Chapter 5

Conclusion

This proof-of-concept study sought to investigate whether an online adaptive microlearning system, Teaching Cells, was consistent with DLPs in rural Chinese eighth-grade students and helped them learn as a supplement to their public school experience. This chapter concludes the study of a new, innovative online adaptive microlearning system, Teaching Cells, which aims to improve deeper learning in rural Chinese public school students.

Summary of Procedures

A prototype of the online adaptive microlearning system (i.e., Teaching Cell) was created adhering to DLPs defined by Wickersham and McGee (2008). Teaching Cell contained a lesson on Wu Zetian, the first empress in Chinese history, which is typically provided in seventh grade. Students from four eighth-grade classrooms at a rural Chinese public school were recruited to use the prototype Teaching Cell during the Fall semester of 2022.

This mixed-methods study collected both quantitative and qualitative data. The quantitative data obtained from the Teaching Cell were analyzed to determine the level that Teaching Cell was consistent with DLPs. Qualitative data obtained from three participants who completed their engagement in the Teaching Cell were analyzed to make sure the main findings from the quantitative data were based on participants' experience.

Participant Demographics

In the four classes at the Chang'an District Middle School, Shaanxi province, China, that accepted the study invitation (potential pool of 183 eighth-grade students), 145 participated in the study (response rate 79.23%). The gender distribution was fairly even (Female 46%, Male 45%, Did not want to say 9%), and most participants (90%) were age 13. While all participants responded to demographic questions, they did not complete all seven steps in the Teaching Cell. The highest participation was Step 2 and Step 3 (both 34%), and the lowest participation was Step 1 and Step 6 (14%).

Summary of Findings

This section starts with a summary of the findings from both quantitative and qualitative data analyses associated with research questions. Interpretations of the findings are then provided.

The first research question stated, “Does the adaptive microlearning module promote the learning engaging in active learning?” The findings from Step 2 (Ask Questions) and Step 7 (Evaluation) of Teaching Cell showed that the Teaching Cell items were realistic, and participants actively engaged in their learning by asking many questions. Interview responses aligned with these findings, suggesting that Teaching Cell supports the Active Learning DLP.

The second research question was, “Does the adaptive microlearning module inspire the learner to create *learner context*?” Although the quantitative data analysis revealed guidance elements were utilized limitedly during Step 3 (Guidance), interviewees expressed otherwise. It is, however, noted that there exists the possibility that interviewees change their behavior when they are aware of being watched. As such, with the lack of utilizing guidance elements, the findings may suggest that Teaching Cell does not adequately support the Learner Context DLP.

The third research question was, “Does the adaptive microlearning module create an *engaged learner*?” The findings from Step 4 (Teaching) and Step 7 (Evaluation) revealed that limited participants engaged in all available instructional elements, although the majority of the participants engaged in some instructional elements and rated their engagement high. With the aligned interview responses, these findings suggest that Teaching Cell supports Engaged Learner DLP but only weakly.

The fourth research question stated, “Is the adaptive microlearning module associated with *learner ownership*?” The findings from Step 5 (Exercise) and Step 7 (Evaluation) uncovered that only limited participants used all available exercise elements, although most participants used some exercise elements and rated themselves high in taking responsibility for their own learning. While interview data offered some evidence of learner ownership, the overall findings suggest that Teaching Cell supports the Learner Ownership DLP but only weakly.

The fifth research question was, “Is the adaptive microlearning module an example of *technology-supported learning*?” The findings from the participants’ device information and Step 7 (Evaluation) showed that while Teaching Cell supports diverse device types, participants experienced technology issues while accessing Teaching Cell as evidenced in both quantitative and qualitative data analyses. These findings hint that Teaching Cell supports the Technology-supported Learning DLP but only weakly.

The sixth research question stated, “Is the adaptive microlearning module an example of *intuitive design*?” The finding from Step 7 (Evaluation) informed that participants experienced intuitive and easy navigation in general. The interview responses, however, offered contradicting evidence. These findings, thus, suggest that Teaching Cell does not adequately support the Intuitive Design DLP.

The seventh research question stated, “Does the microlearning module lead the learner to participate in *engaged activities*?” The findings from many steps (i.e., Step 3 (Guidance), Step 4 (Teaching), Step 5 (Exercise), and Step 7 (Evaluation)), along with the interview responses, collectively suggest that Teaching Cell supports the Engaged Activity DLP.

The final research question was, “Is the adaptive microlearning module associated with *facilitative learning practices*?” The performance contrast between Step 6 (Post-test and Pre-test, findings revealed that only half of the participants benefited from Teaching Cell. Interview responses, however, offered contradicting evidence. Acknowledging the possibility that interviewees change their behavior when they are aware of being watched, the findings may suggest Teaching Cell does not adequately support the Facilitative Learning Practices DLP.

Interpretation

This proof-of-concept study demonstrated that adaptive microlearning could offer some levels of deeper learning experience in a sample of rural Chinese eighth graders. The prototype adaptive microlearning system, Teaching Cell, designed to incorporate eight DLPs as defined by Wickersham and McGee (2008), was able to support the DLPs of active learning and engaged activities. Even when learners skipped parts of the Teaching Cell, they were engaged with the parts that interested them. In the interviews, they explained that they were pleased that they could skip the parts of the Teaching Cell they did not want to use and were able to use and reuse elements for efficient preview and review. This provides evidence of the DLPs of learner context, engaged learner, and learner ownership. Through the feedback in the evaluation part of the Teaching Cell and the interviews, it became clear that the learners enjoyed that they could set their own goals and timelines with the Teaching Cell. They were especially pleased that they were not forced through a particular learning pathway in the Teaching Cell and could choose their own pathways.

Due to the cost and technology mobile features, and the development of Internet service in rural area in China, the concept of adaptive microlearning could be potential solution to foster deeper learning in rural area to solve the imbalanced learning resource problem.

The aspects of the Teaching Cell prototype that were less aligned with DLPs may relate to two main issues. First, as the platform used for the experiment (i.e., Qualtrics) had to be accessed from China, there was network latency. This latency caused participants to stay connected to the Teaching Cell, as evidenced in many duplicates. Second, due to the design and function of tracking students' learning process, Qualtrics could be the best solution for this research project. However, as Qualtrics is mainly an online survey tool rather than a research platform supporting design choices in the Teaching Cell, navigation options included in Teaching Cell were less than ideal.

Findings Related to the Literature

Education in China and Deeper Learning

The findings from this study connected to deeper learning capabilities, as they show that Teaching Cells were able to empower learners to master educational content, engage in critical thinking, solve problems, work on teams, communicate effectively, use academic reasoning, and be self-directed in their learning (Martinez & McGrath, 2014). In addition, the findings also demonstrated a solution to the resource unbalance issue in China urban and rural area that utilized educational technology for rural students (Wang et al., 2018).

Diverse frameworks for deeper learning have been suggested, but the current study needed a deeper learning framework that is applicable to online learning of public school curricula in rural Chinese middle school students. The chosen framework by Wickersham and McGee (2008) describes nine DLPs, eight of which were investigated in the Teaching Cells prototype of an adaptive microlearning system in this study.

The literature identifies many factors that influence deeper learning. An important factor is the learner's intention, as most deeper learning activities require learners to motivate themselves along a learning journey (Dweck et al., 2014). From the findings of this study, the learners engaged in the learning process and indicated they would like to learn more with Teaching Cell in the future during the interview. This supported the argument that the Teaching Cell successfully facilitated the learner's understanding of the material. Evidence like this is consistent with the scientific literature, such as Hattie and Donoghue (2016), who argue that if the learner's intention is surface learning, then deeper learning would not occur.

As learners typically have to manage their own learning journey when engaging in learning, student motivation also has a strong influence on deeper learning (Abdul Jabbar & Felicia, 2015; Dweck et al., 2014; Farrington, 2013; Hattie & Donoghue, 2016; Jong, 2015; Kember, 2000; Ryan & Deci, 2017). Student motivation can come from different sources, such as collective motivation from in-class participation (Herrmann, 2013). The findings from Teaching Cell data indicated that students were engaging and active learning during the learning process. They also indicated their interest in using the Teaching Cell in their interviews. According to Farrington (2013), student motivation is associated with consistent engagement in deeper learning activities, and this was seen in learners using the Teaching Cell.

Student engagement is a common DLP across various frameworks (Blanco et al., 2013; Milligan et al., 2013). While Milligan and colleagues (2013) suggested three types of online learners (i.e., active participants, passive participants, and lurkers), there would only be two types of participants in the Teaching Cell (active and passive participants) due to the lack of a social component. Active participants were exposed to personalized learning. In the qualitative portion, respondents commented on how much they liked the ability to use only the parts of the Teaching Cell they wanted, and to exit it whenever they wanted, suggesting they valued the personalized experience. These combined findings offer evidence that adaptive, personalized learning has a positive influence on student engagement, as was suggested in the literature (e.g., Blanco et al., 2013).

Gamification encourages student engagement along with active learning, which is associated with knowledge uptake (Annetta et al., 2009; Jong, 2015). Games that represent more of a simulation of real-world experience leverage deeper learning principles and can be engaging without a competitive component (Grover et al., 2015; Henning et al., 2014). Gamification simulations can thus be especially helpful for developing applied problem-solving skills (Connolly & Stanfield, 2006). In the Teaching Cell, this type of gamification is seen in the Jeopardy-like game and the link game, which simulate real-world classroom experiences. This self-competition (competition with their own past selves) serves more as a self-test or self-assessment while also being a simulation. As such, it does not suffer from introducing the social pressure associated with competitive gamification learning modules that involve competition with peers, or from other uncertainty in gamification modules that has been found to be demotivating (Howard-Jones & Demetriou, 2009; Jong, 2015).

Another feature that influences deeper learning is learner-engaged assessment, where the learner uses the learning tool to undergo a self-assessment (Berger et al., 2014; Panadero & Romero, 2014). Learner-engaged assessment has been shown to motivate learners, as they can receive feedback about how they are progressing along their learning journey (Berger et al., 2014). In Teaching Cell, learners could take (and retake) pretest and post-test, and also, play the link game and the Jeopardy-like game as types of self-assessments. These features may have maintained higher levels of motivation among learners who were actually engaged, encouraging them to continue to use the Teaching Cell. In addition, from the interview, students who indicated they were using these learner-engaged assessments said that these assessments made them feel more engaged during learning process.

Learner attitude also plays a role in deeper learning. For example, those who do not like online learning will be less likely to benefit from it, and those not interested in the topic may not feel intellectually engaged (Jong, 2015; Kauffman, 2015). The data from the self-evaluation showed that learners who used the Teaching Cell had different attitudes and used it in different ways. Based on literature, a way to encourage consistent use of an online learning system is to provide learners with different ways to engage with the same material (Kauffman, 2015). The findings of Teaching Cell show that because students could choose different learning items, they were more engaged because they could make choices.

Ultimately, deeper learning frameworks speak to the concept of trying to induce metacognition in learners through their active engagement with learning tools (Dori, 2017; Wickersham & McGee, 2008). Metacognition represents the learner operating at a higher level of knowledge, requiring more executive function to coordinate learning activities and behaviors (Schultz, 2012). Metacognition is stimulated in a learning environment through interaction, strategizing learning, and keeping track of processes, tasks, and goals (Boyer et al., 2006; Dori, 2017; Huffaker & Calvert, 2003). In the Teaching Cell, the responses to the evaluation showed that participants interacted with different Teaching Cell elements, and almost three-fourths of students indicated they would choose at least one teaching activities and at least one exercise activities. The qualitative responses also revealed that learners used diverse Teaching Cell elements (e.g., preview, review for a test, quick learning lesson).

In addition to the aforementioned factors that influence deeper learning, best practices of deeper learning suggest that making learning contextual (e.g., solving real-world problems) helps improve active learning DLP (Crocco et al., 2016; Jong, 2015; Wickersham & McGee, 2008). Both evaluation items of level of realism showed that almost three-fourths of students agreed that they perceived an authentic learning context in the Teaching Cell.

Best practices of deeper learning also recognize the important role that course management systems (CMS's) play for successful DLPs (Carmean & Haefner, 2002;

Lloyd, 2014; Wickersham & McGee, 2008). For example, whether a CMS functions smoothly in all operations that it supports (e.g., social interaction, online assessment, gamification) and whether the CMS serves appropriate learning resources in response to users' learning needs in real-time will influence the implementation of DLPs (Lloyd, 2014; Wickersham & McGee, 2008). The Teaching Cell, unfortunately, was not consistent with the technology-supported DLP and the intuitive design DLP, as evidenced in both quantitative log-in issues and qualitative responses. These are significant weaknesses of the current Teaching Cell prototype, which warrant future improvement to better support DLPs.

Educational Technology

Educational technologies should leverage instructional strategies for a digital environment (Aleven et al., 2016; Dede, 2014; Paramythis & Loidl-Reisinger, 2004; VanderArk & Schneider, 2012). Digital learning environments can foster self-direction in learning, personalized learning experiences, and innovative self-assessments (Dede, 2014). Digital learning can also help students access different learning resources, experience learning environments customized for their intellectual needs, and prepare for future work tasks using simulations (VanderArk & Schneider, 2012). Most importantly, the digital learning environment allows lessons to be adaptive to the learner's needs (Aleven et al., 2016; Brusilovsky, 1999; Paramythis & Loidl-Reisinger, 2004). The current study revealed that Teaching Cell offered a positive learning experience to the participants by offering many advantages of digital learning.

While adaptive learning finds its root in intelligent tutoring systems, intelligent tutoring systems have mainly focused on teaching STEM topics to higher education learners (Mousavinasab et al., 2021; Xie et al., 2019). The Teaching Cell, however, focused on teaching a history topic to rural Chinese primary school learners. Nonetheless, participants using the Teaching Cell reported positive learning gains and satisfaction in the experience with the innovative and novel learning system, consistent with past intelligent tutoring systems studies (e.g., Kulik & Fletcher, 2016; Xie et al., 2019).

One of the main characteristics of the Teaching Cell is Microlearning. Microlearning prevents cognitive overload by offering a small amount of information at a time (Bruck et al., 2012; Jahnke et al., 2020; Jomah et al., 2016; Sun, Cui, Yong, et al., 2015; Sun et al., 2018). Participants in the current study expressed satisfaction with the microlearning aspect of the Teaching Cell. For example, participants indicated that they liked the possibility of engaging in short lessons or learning blocks (in line with Jahnke et al., 2020) for short periods of time (in line with Sun et al., 2018) where they were not being forced through a particular, preset learning pathway (in line with Sun, Cui, Yong et al., 2015). Participants also expressed appreciation that they could engage in review and preview of the material with breaks in between (in line with Bruck et al, 2012), easily review and preview short lessons, and access from anywhere anytime for short periods of time. It was also noted that participants felt the microlearning complemented their classroom learning experience.

Limitations of the Study

The study investigated different aspects and factors of deeper learning using a newly invented teaching protocol and an adaptive micro learning platform called Teaching Cells. The Teaching Cell platform offers a possible solution for rural areas in China to address the shortage of educational resources while fostering students' deeper learning with educational technology. The study, however, is not without limitations and delimitations. The main limitation is network latency. The current study implemented the Teaching Cell in Qualtrics, which has its server outside of China. As participants accessed the Teaching Cell from China, however, they suffered from network latency. In many cases, this latency caused participants to experience difficulty staying connected to the Teaching Cell. It is thus desired to develop future versions of the Teaching Cell using China-based technology that is easily accessible in China. The findings from the current study and future versions could then offer a more accurate assessment of the Teaching Cell. A related limitation is that not all data needed for the study could be gathered due to the network latency. Although almost 150 eighth graders initiated their participation, many could not provide complete data due to issues with connectivity resulting in missing data.

Delimitations of the Study

One of the main delimitations relates to the study platform. The current study used Qualtrics to collect participant interaction data while they engaged in the Teaching Cell elements, which were implemented in Qualtrics. However, as Qualtrics is mainly an online survey platform offering limited design choices, navigation options included in the Teaching Cell were limited, thus influencing participants' experience with Teaching Cell. If future research studies Teaching Cell prototypes utilizing a more suitable CMS that includes tracking and interactive functions, the results would likely reflect that users felt the design was more intuitive.

The second delimitation is the chosen DLP framework, modeled by Wickersham and McGee (2008). Although this framework was intentionally chosen for its ability to evaluate DLPs in online learning, there are many other deeper learning models highlighting other DLPs that are not emphasized in the framework that the current study adopted. While many frameworks share some commonalities, adoption of other frameworks could yield slightly different findings. This and future research into online deeper learning should adhere to a fundamental framework of deeper learning, which should be agreed-upon or urgently developed.

The third delimitation is that the Teaching Cell had only one topic with only a few elements in each step. While these delimitations were put in place to make the dissertation project manageable, they limited the ability to study the evolutionary nature of the adaptive microlearning system. Future research could study Teaching Cell prototypes that include more units in order to facilitate more realistic connections along the student's learning map, and to provide a more personalized experience through adaptive features. These additions may help researchers get a clearer estimate as to how an adaptive microlearning platform could benefit students' deeper learning.

Implications

One of the most apparent implications from the evidence from the current proof-of-concept study could be that it uncovered the potential of the online adaptive microlearning system as a way to implement deeper learning. While the prototype (Teaching Cell) will need to undergo multiple iterations to reach its optimal state in supporting deeper learning principles, the findings nonetheless showed how such a system could be used as a quality supplemental learning aid for learners from rural China.

One apparent practical implication could be the insight gained about learner motivation. Results from the study indicated learners enjoyed many deeper learning features in the prototype system (Teaching Cell). Learners particularly appreciated the ability to enter and exit the Teaching Cell of their choosing, navigate through different steps of the system, and use diverse elements to meet their learning needs. This flexibility appeared to positively influence learners' motivation to use the Teaching Cell, offering valuable insights to online curriculum designers who endeavor to increase learner motivation.

While the study was designed to help disadvantaged students from rural China, it is worth emphasizing that research on online adaptive microlearning systems like Teaching Cells can be extended to improve equitability in education students from urban China as well. As educational reform is continuous in China, recently, the government announced a new policy called Double Reduction. The policy's intention is to reduce the burden of repeated homework and unmeaningful learning among students to save more time to teach metacognitive skills, such as research skills, critical thinking, cooking, and so on. Given that the Teaching Cell supported most of the DLPs in this study, the concept of an online adaptive microlearning system like Teaching Cells could be used as a supplement to classroom learning as a possible learning resource to support any students who are in need of learning support. Use of the Teaching Cell would create a personalized learning map based on the learner's interests, and could foster metacognition and a growth mindset. Additionally, design aspects of the Teaching Cell which learners preferred could be implemented into Chinese online learning systems.

Recommendations for Future Research

While the Teaching Cell prototype demonstrated a potential for imparting a deeper learning experience for learners, the study also uncovered many exciting avenues for future research. First, the discrepancy observed between the quantitative and qualitative data analysis (e.g., learning assessed through the pre-test and post-test compared to interviews) warrants additional research. The discrepancy could be caused by inappropriate measurement using the pre-test and post-test data, but it could also be due to the awareness of the participants who were being interviewed of being observed, which consequently yielded biased responses. How to improve the measurement of facilitative learning practices in the Teaching Cell should be the subject of future research. Consideration of facilitative learning practices brings up the issue of teacher involvement in the Teaching Cell. In the current prototype, teacher-student interaction was not implemented; however, the inclusion of such interaction could play a significant role in the success of future Teaching Cells, and should be the subject of future research.

Design iterations are the basic building blocks of any system design. With the insights gained from the current study, especially the issues faced due to the limited flexibility of the Teaching Cell platform, future Teaching Cell iterations will need to be implemented on a suitable CMS platform to ensure all DLPs could be adequately addressed. Particular attention should be paid to the ability to build intellectuality and intelligent automation into the Teaching Cell, as well as develop an intuitive interface that supports easy navigation. Future improvements should also ensure Teaching Cells are can undergo evolutionary growth through manual or automatic procedures.

In addition to the areas mentioned above, future research may also consider learner-learner interaction in the Teaching Cell design, as the sense of connectedness perceived by a learner can influence learning motivation and consequent behavior (see Ryan & Deci, 2017). It may also be prudent to involve diverse learners from different educational settings (e.g., rural public school, urban public school, and so on) to gain further insights into how well Teaching Cells respond to various learning needs.

Summary

The current proof-of-concept study demonstrated that the prototype of an online adaptive microlearning system supported five of the eight investigated DLPs. The prototype was well-received by the target audience of rural Chinese middle school. They expressed their satisfaction with the prototype and indicated the prototype was refreshingly different from other online learning experiences. In anticipation of improving the prototype Teaching Cell by responding to the aspects that showed inconsistency with DLPs (e.g., technology support and intuitive design), the envisioned future Teaching Cell system is anticipated to serve as a helpful technological supplement to curricular learning of rural Chinese middle school students. The system has great potential to serve as an online learning tool that students enjoy using, and seek out to complement their other out-of-school learning activities.

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Appendices

Appendix A

Translation to English of Elements in the Teaching Step

Narration in the Teaching Video (English Translation)

- Wu Zetian, China's first and the only empress in history, entered the palace at the age of 14 as the wife of Tang Taizong and was later promoted to the queen during Tang Gaozong's reign. AD690, she became the empress and established the kingdom of "Wu Zhou." In the men's power-dominant era, her achievement was astonishing. This is all possible because she exceeded the rest in bravery and wisdom.
- Wu Zetian suggested and developed a new imperial examination system. The system consisted of two parts: the original literature examination and a newly added military examination. She placed emphasis on talents and promoted employing people with better abilities.
- Wu adopted the Tang Taizong's strategy of "If they surrender, then calm them; if they rebel, then defeat them" to deploy a strong foreign policy to defeat the invasion. She achieved big success.
- During Wu's reign, she placed emphasis on literature and history. She repaired historical buildings and developed agriculture and crafts. She believed that "agriculture is the basis of a country" and made three types of religions compatible with developing them.

- Wu established the political and cultural basis of Kaiyuan Shengshi. Mr. Lu Xun praised her as "the bridge of Zhenguan, the start of Kaiyuan."
- Wu Zetian also had her shortages. She killed many people, especially prior to her reign. She killed many government officers, and it led to big chaos.
- Some cool facts about Wu Zetian:
    1. The country name of Japan was created by Wu Zetian. Before her, it was Wunu Country, made by Liu Xiu.
    2. Wu Zetian was not nice to her family and compulsively changed their surname to Fu, which means devious, to please Tang Gaozong.
    3. Wu Zetian born many sons. Even when she was 38 years old, she gave birth to Ruizong, the father of the future emperor Xuanzong.
    4. Wu's tomb is without any words and has the sculpting of eight dragons. The height is about 7.53 meters, just like 3 levels building. If you stand there, you only can look up at it.
    5. Wu Zetian created 15 new characters, including her own name 'Kong', which means women could be powerful as men.
    6. Li Bai, a famous poetry writer, has never had any competitors. His wife, however, criticized that Bai's love poems are terrible compared to Wu's.
    7. During Wu's reign, the fisherman only could eat seaweed because she declared that eating living species was not allowed.
    8. Wu invented a seal line to ensure the admission judge could not see candidates' names to keep the exam fair.

Audio Book (English Translation)

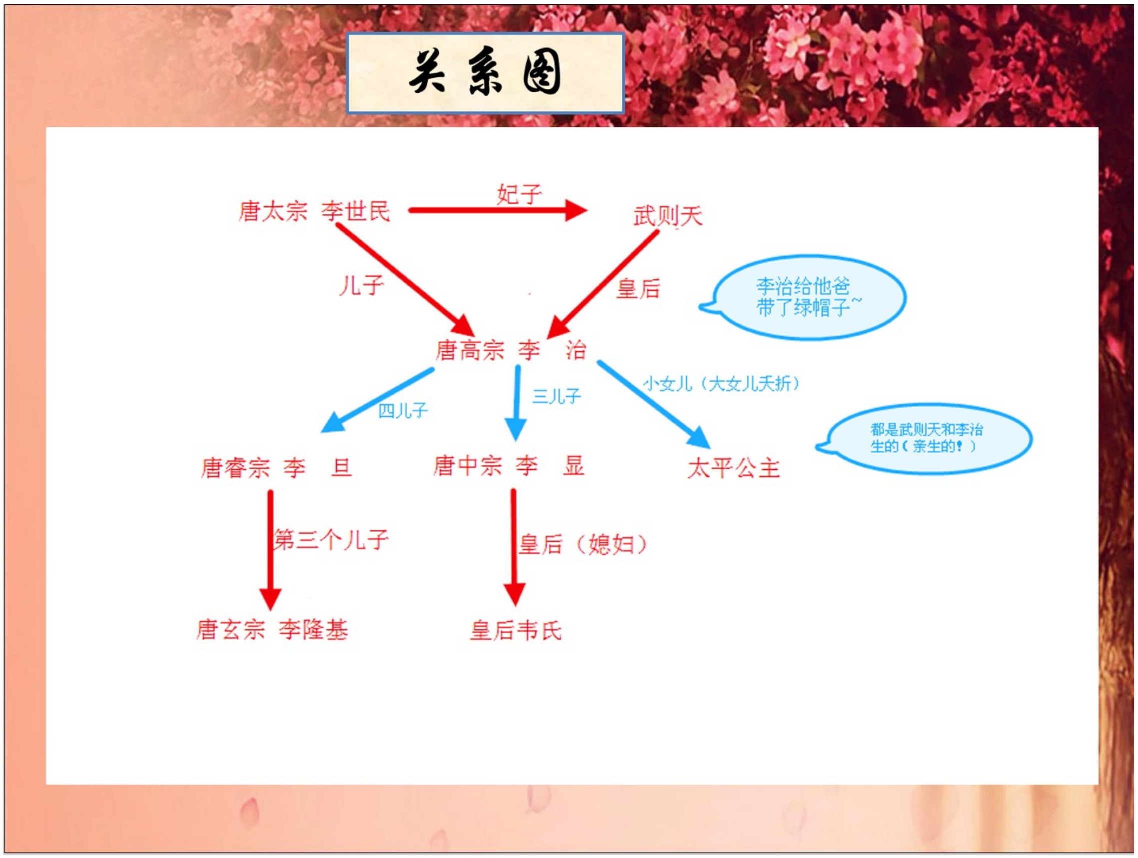
Wu Zetian (Empress of Wu Zhou)

- (Poem of Wu)
    - [Heritage of Zhenguan, and start of Kaiyuan
    - The men always be the emperor in the history
    - Qian tomb stone has all her words]

- Wu Zetian, AD.624-705
- Originally named Zhao, then changed to another character with the same pronunciation.
- Originally from Binzhou, Wenshui. Now is located in Shanxi province, Lvliang City, Wenshui District.
- Politician and became Empress for 15 years.
- She called her family the legacy of the previous Emperor's family. Based on the history of her ancestors, she established the Wu Zhou dynasty.
- Wu Zetian was the little daughter of Wu Jihou. At the age of 14, she was chosen as an imperial concubine of Taizong. Taizong gave her nickname as Wumei.
- She was promoted to be the queen of Gaozong during Gaozong's reign.
- She was called "two Saints" with Gaozong.
- AD683, as the mother of future emperors Zhongzong and Ruizong, she seized political power.
- AD690, she became the Empress of Wu Zhou.
- AD705, she ended her Empress reign.

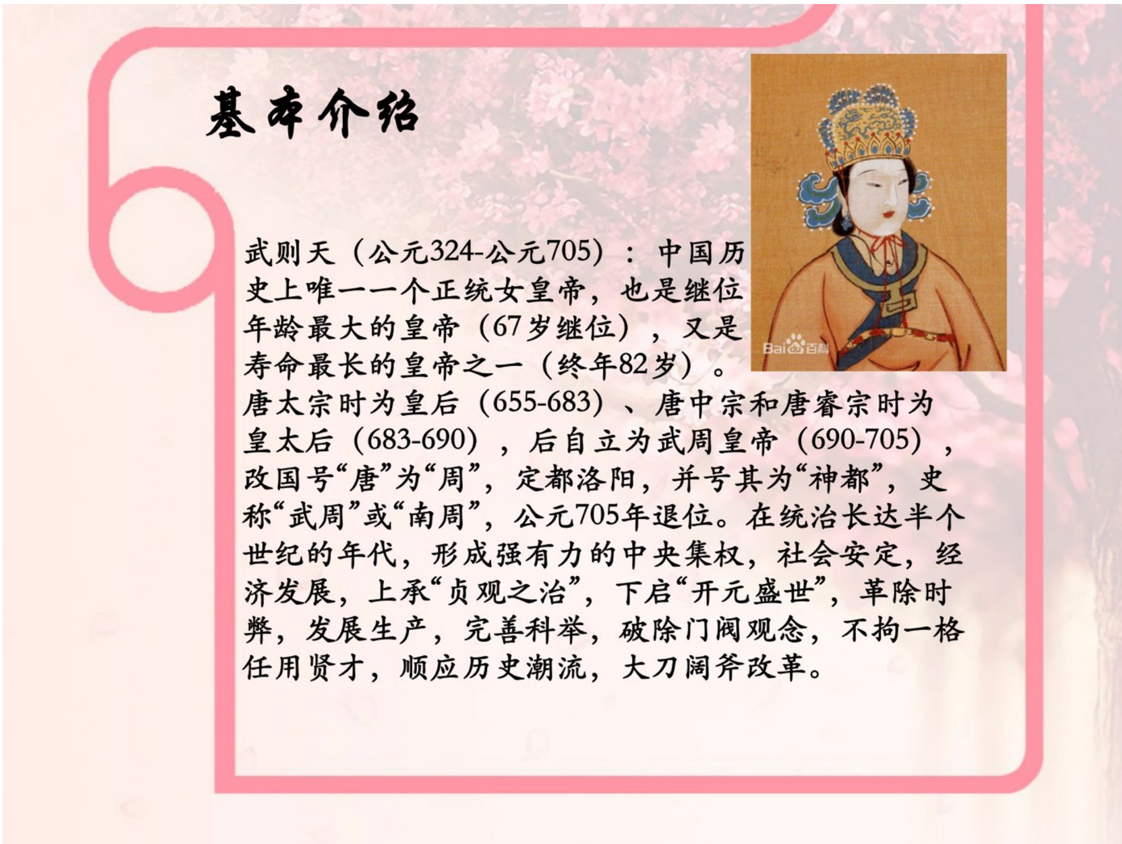
- Empress Wu emphasized recruiting talented people. First created final imperial examination for imperial examination system.
- During her reign, many talented people, such as Di Renjie, Zhang Jianzhi, and Yao Cong, served the country.
- During her reign, policies and society were stable. Foreign policies were very good, culture was recovered and developed, and people lived happy and wealthy life. The so-called succession of Zhenguan provided her grandson, Xuanzong, the base for lasting political stability.
- She is the bridge and connector of the Zhenguan Golden Years and Kaiyuan Flourish Age.
- Wu, as a woman, became an Empress, cracking down on the traditional ethical value of that time. She needed both bravery and talent, especially extraordinary efforts.
- She used many strategies to squeeze out Li Family (Tang Dynasty) to stabilize her power, including eliminating the Emperor’s prince. Consequently, she received many negative comments.
- Wu studied very hard, read many books, and was good at writing poetry. Her calligraphy contains men’s mettle and shows the spirit of her political views.
- She was buried with Gaozong at the Qian tomb and got a monument without inscriptions, which showed her wisdom.
- Wu’s poems are very sophisticated and pretty. (An example of her poem)

Empress Wu Zetian

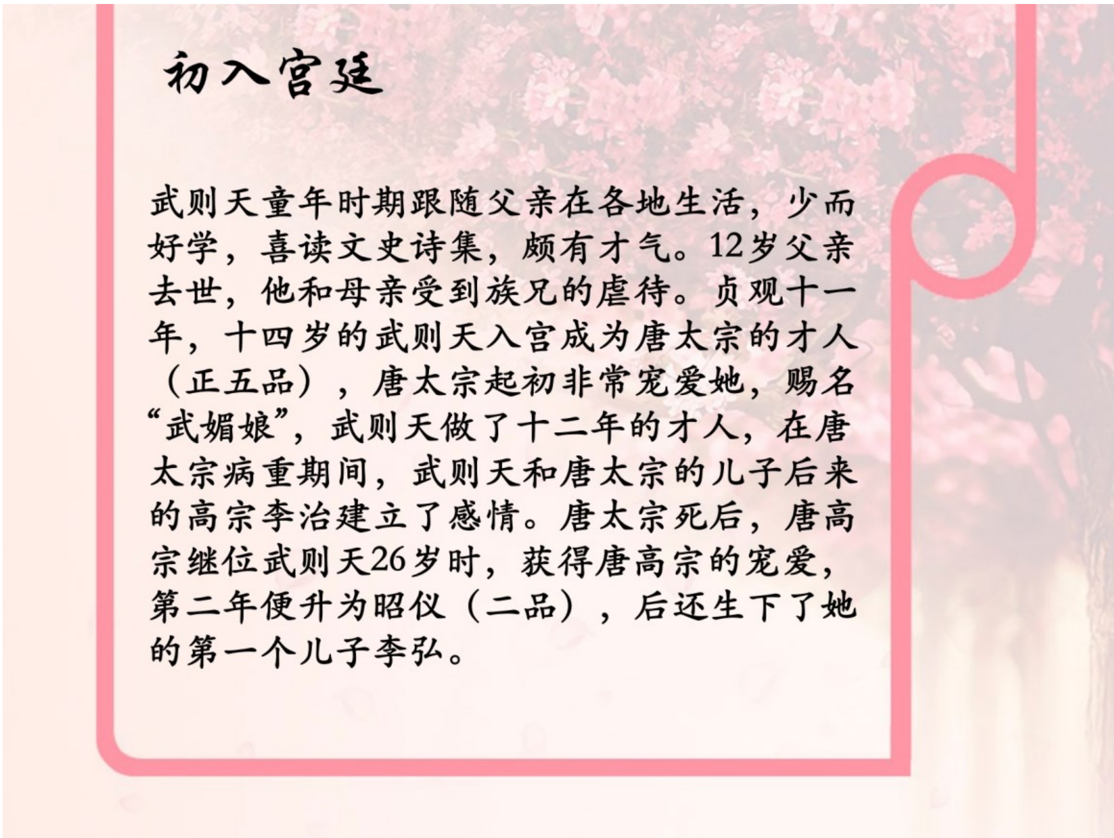


The relationship network of the Wu and Li family

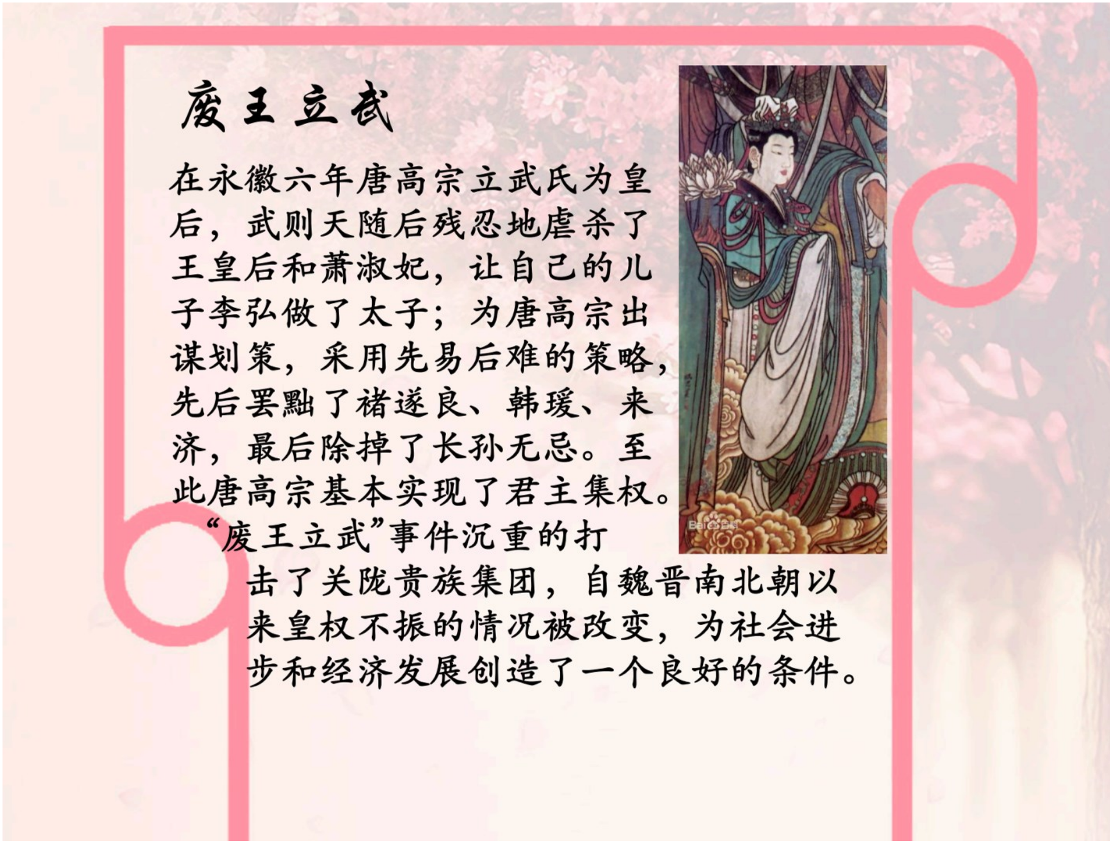
Table of contents: Intro of Wu Zetian, Wu's life introduction, Wu's contribution, and comments of Wu from other famous people.



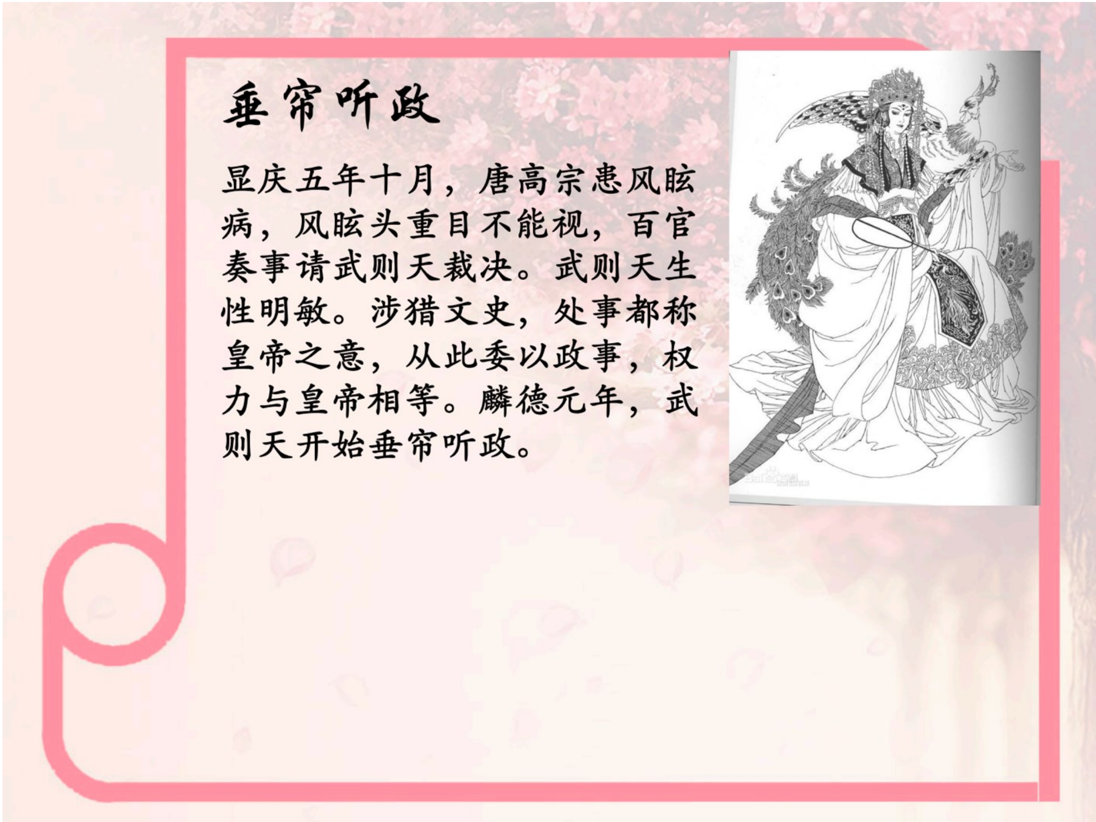
Basic Introduction: Wu Zetian (324 AD - 705 AD) :
The only proper female emperor in history and the oldest emperor, who succeeded at 67, was one of the longest-lived emperors (82 years).
The reigns of Emperor Taizong (655-683), Empress Dowager (683-690), Empress Dowager (683-690), and emperor Wuzhou (690-705) were proclaimed emperors of the Tang Dynasty (690-705). The imperial title was changed from Tang to Zhou, and Luoyang was established as the capital of The Tang Dynasty. During the reign of half a century, she formed strong centralized power, social stability, and economic development, inheriting the "Zhenguan golden years" (the beginning of the "Kaiyuan prosperous age"). She accomplished drastic reform by abolishing the issues, developing production, improving the imperial examination, abolishing the concept of classes, and appointing talents, all while conforming to the historical trend.



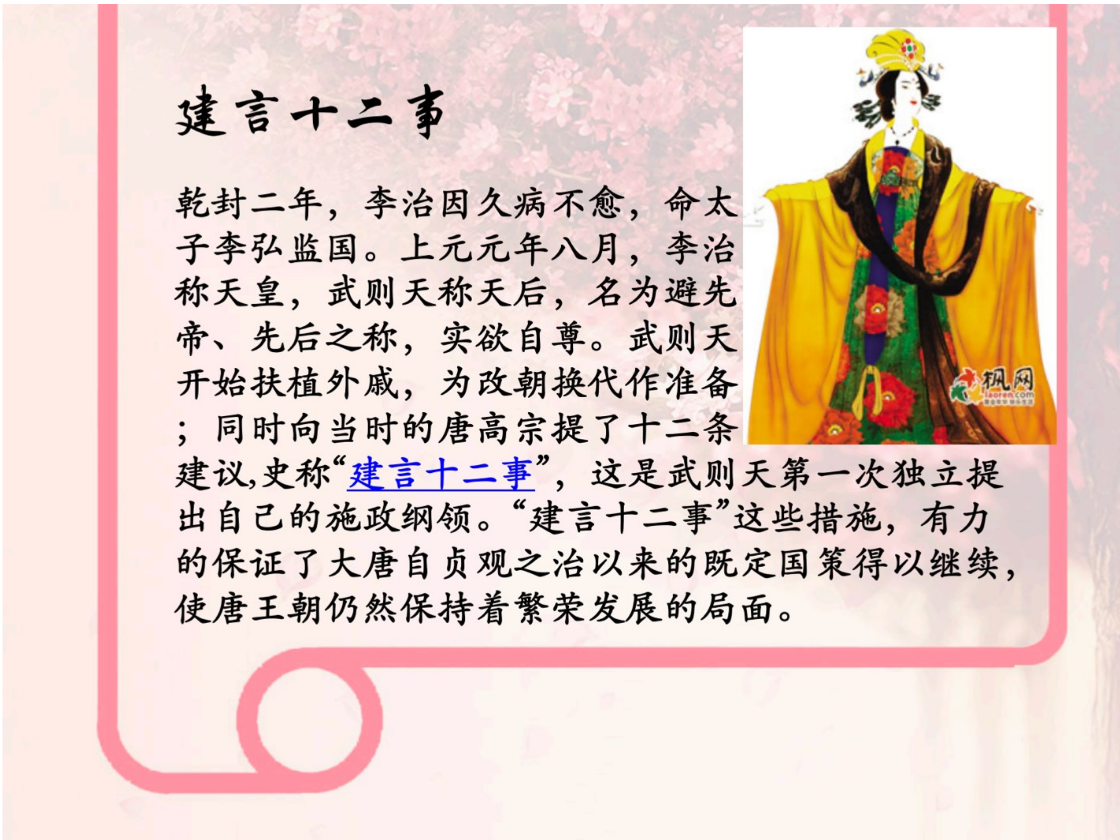
Start her royal life: During her childhood, Wu Zetian lived with her father in various places. When her father died when she was 12 years old, she and her mother were abused by their male family members. In the eleventh year of Zhenguan, the 14-year-old Wu Zetian entered the palace and became a talented person (concubine) of Tang Taizong (the fifth grade). Tang Taizong loved her very much at first and gave her the name "Wu Meiniang". Wu Zetian was a talented person for twelve years. During Emperor Taizong's serious illness, his son Li Zhi, later Gaozong, and Wu Zetian established a relationship. After Tang Taizong's death, Tang Gaozong took Wu Zetian when she was 26 years old, and she was favored by Tang Gaozong. The following year, she was promoted to Zhaoyi (second grade) and later gave birth to her first son, Li Hong.



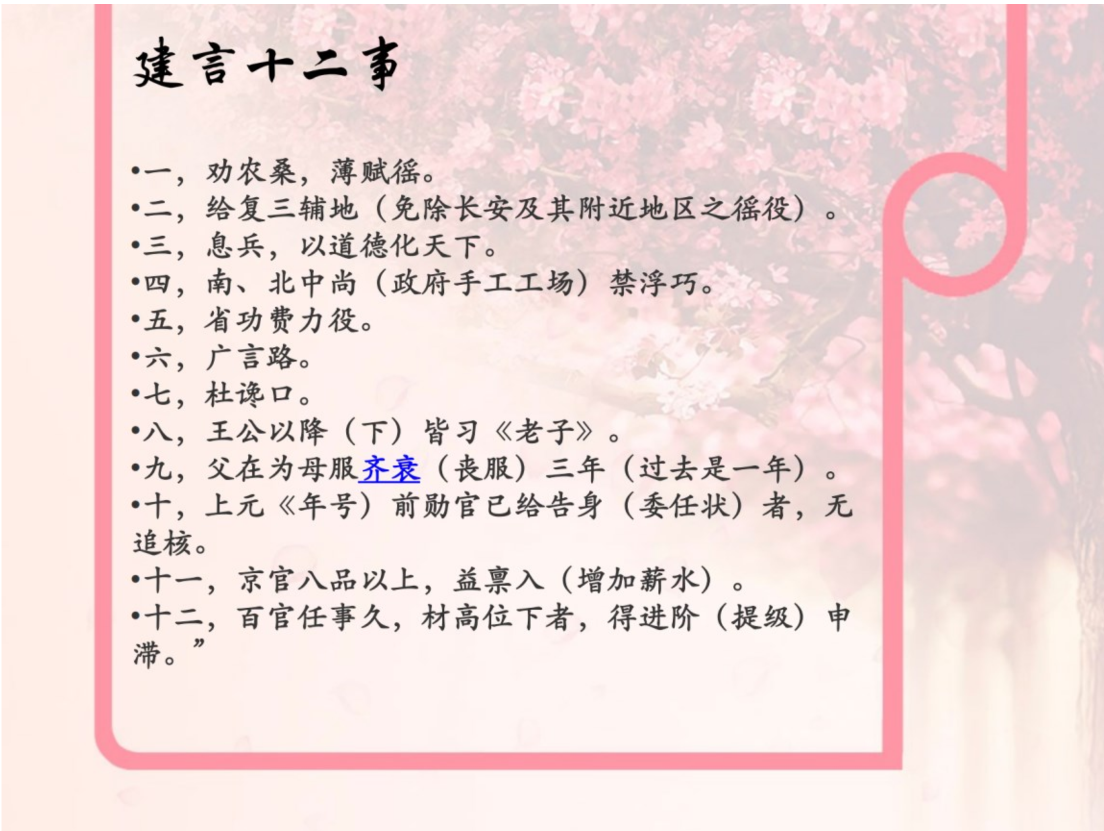
Abolish Wang and confer title to Wu: In the sixth year of Emperor Gaozong of Tang, the Emperor established Wu as queen. Later, Wu Zetian brutally killed Queen Wang and Concubine Xiao Shu, and let her own son Li Hong become crown prince. She served Emperor Gaozong by making plans and adopting the strategy of easy first and then difficult. She dismissed Chu Suiliang, Han Yuan, Lai Ji, and finally, the eldest grandson Wuji. Until then, Tang Gaozong had only the basic realization of the centralization of the monarchy. The "Abolition of the Wang and the Establishment of Wu" incident was heavily attacked by the Guanlong noble group since the Wei, Jin, and Southern and Northern Dynasties. The situation in which the imperial power was weak was changed, and the progress of the society was improved. The progress and economic development have created a favorable condition.



Hearing politics under the curtain: Emperor Gaozong suffered from wind dizziness. His head was too heavy to see, and the government officers asked Wu Zetian to adjudicate. Wu Ze was born bright and sensitive. She was involved in literature and history. She did everything according to the emperor's wishes. Since then, she was entrusted with political affairs, and her power became equal to that of the emperor. Wu Zetian began to control the politics behind the curtain.

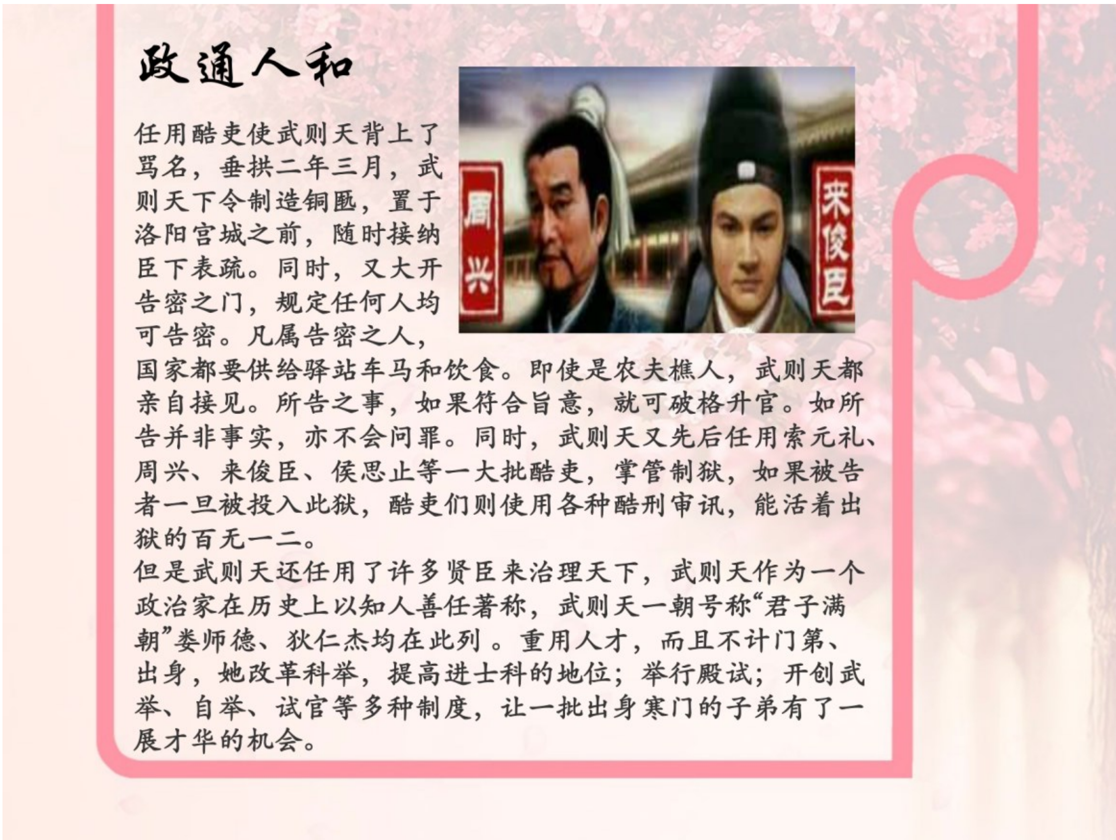


Twelve Things to advise: Gaozong ordered the crown prince Li Hong to supervise the country due to a long illness. In August of the first year of Li Zhi, Wu Zetian was called the queen of heaven. Wu Zetian began to support her relatives to prepare for the change of the dynasty. At the same time, she made 12 suggestions to Tang Gaozong, known in history as " Advice on Twelve Things." This was the first time Wu Zetian independently proposed her own policy program. "Advice on Twelve Things" has effectively ensured that the established national policy of the Tang Dynasty since the reign of Zhenguan can continue so that the Tang Dynasty still maintains prosperity and development.

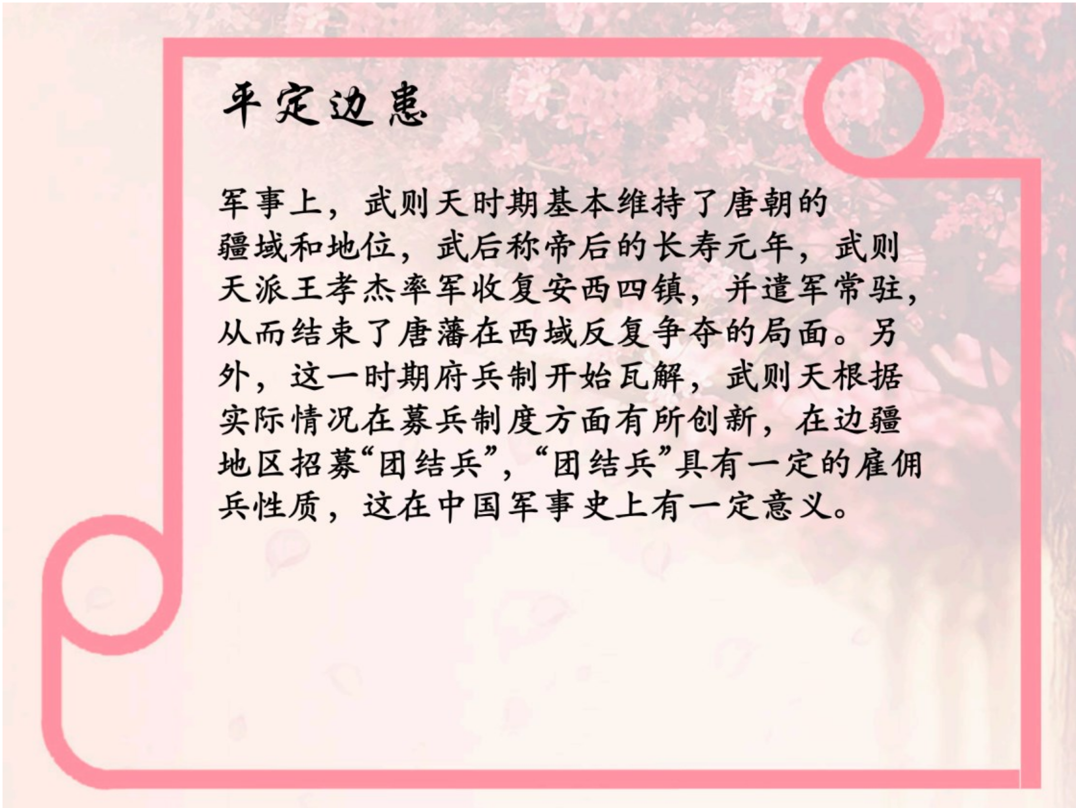


The "Twelve Suggestions"
1. Develop agriculture
2. Reduce tax
3. Stop the war with other kingdoms
4. Ban brothels and gambling
5. Save labor for more useful
6. Expand the freedom of comment of people
7. No rumor
8. Tao Te Ching should be added to the required reading for imperial university students
9. A three-year mourning period should be observed for a mother's death in all cases, not only in those cases when the father was no longer alive.
10. Any meritorious minister who has previously been given a title, the official appointment letter issued, will not be withdrawn
11. Increase salaries for the officer above level eight
12. If an officer has been in the same position too long, some other talented people could be promoted to that position.

Wu had her youngest son, Li Dan, made emperor, known as his temple name Ruizong. She was the absolute ruler, however, both in substance and appearance. Wu did not even follow the customary pretense of hiding behind a screen or curtain and, in whispers, issued commands for the nominal ruler to formally announce, and so her reign was fully recognized. In 690, Wu had Emperor Ruizong yield the throne to her and established the Zhou dynasty, with herself as the imperial ruler (*Huangdi*).

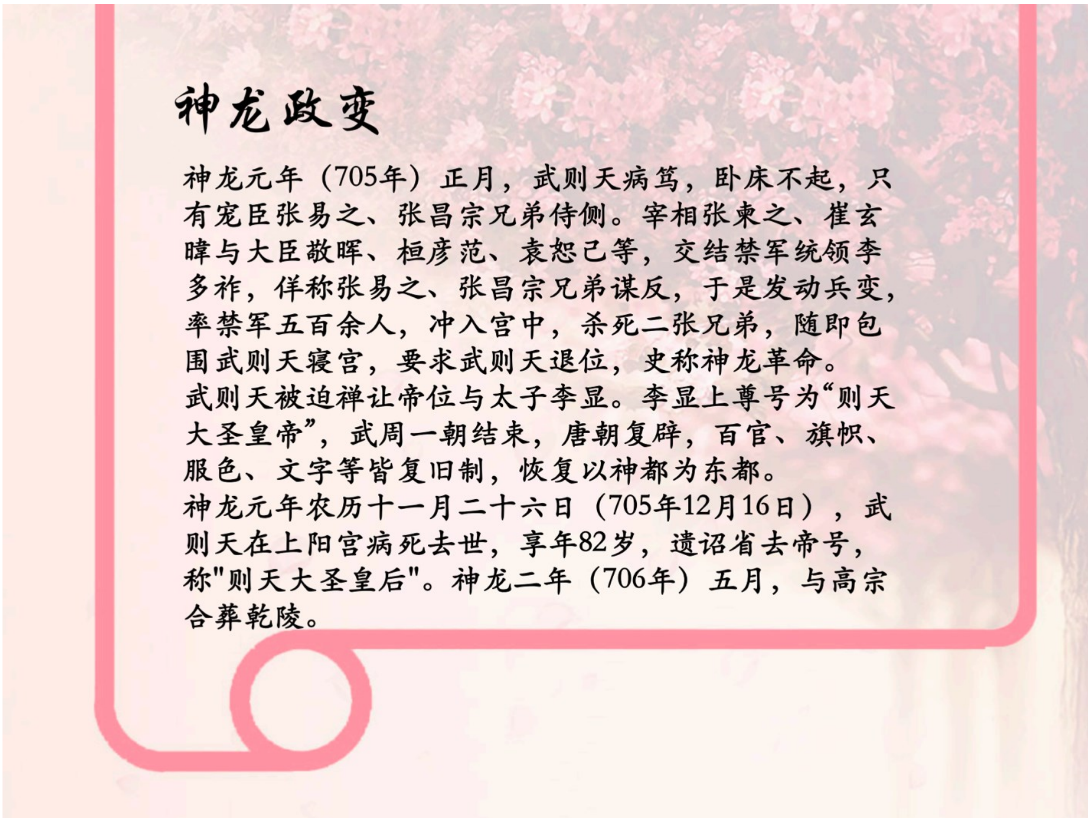


One apparatus of government, which fell into Wu's power, was the imperial examination system: the basic theory and practice of which was to recruit the men, who were the best educated and talented and had the best potential to perform their duties, in government services by testing a pool of candidates to judge them objectively. This pool was males only, and the qualified pool of candidates and resulting placements into official positions were relatively small at the time of Wu's assumed control of the government. The qualities sought in a candidate for government service included determining the potential official's level of literacy in terms of reading and writing as well as his possession of the specific knowledge considered necessary and desirable for a governmental official, such as Confucian precepts on the nature of virtue and theory on the proper ordering of and relationships within society. Wu Zetian continued to use the imperial examination system to recruit civil servants. She introduced major changes in regard to the system that she inherited, including increasing the pool of candidates permitted to take the test by allowing commoners and gentry, who were previously disqualified by their background, to take them. She also expanded the governmental examination system and greatly increased the importance of this method of recruiting government officials, which she did in 693.

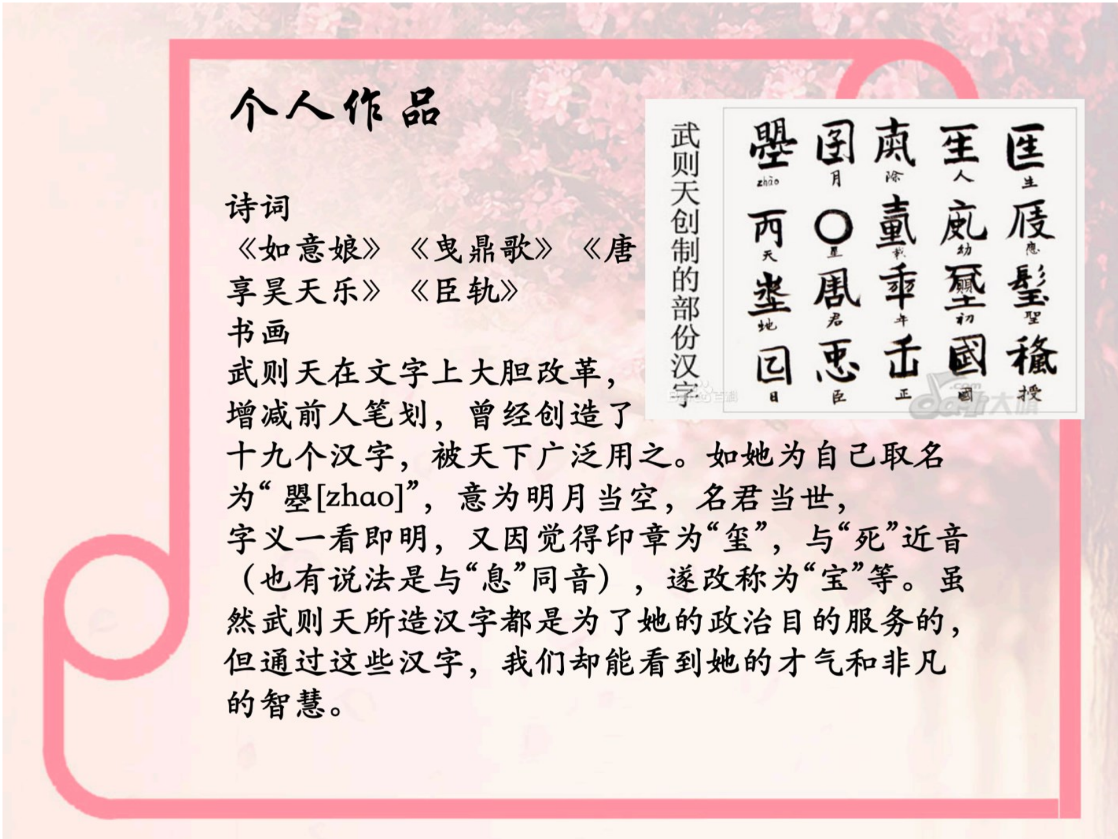


Wu Zetian used her military and diplomatic skills to enhance her position. The *fubing* system of self-supportive soldier-farmer colonies, which provided local militia and labor services for her government, allowed her to maintain her armed forces at reduced expense. She also pursued a policy of military action to expand the empire to its furthest extent ever up to that point in Central Asia. Expansion efforts against Tibet and to the northwest were less successful.

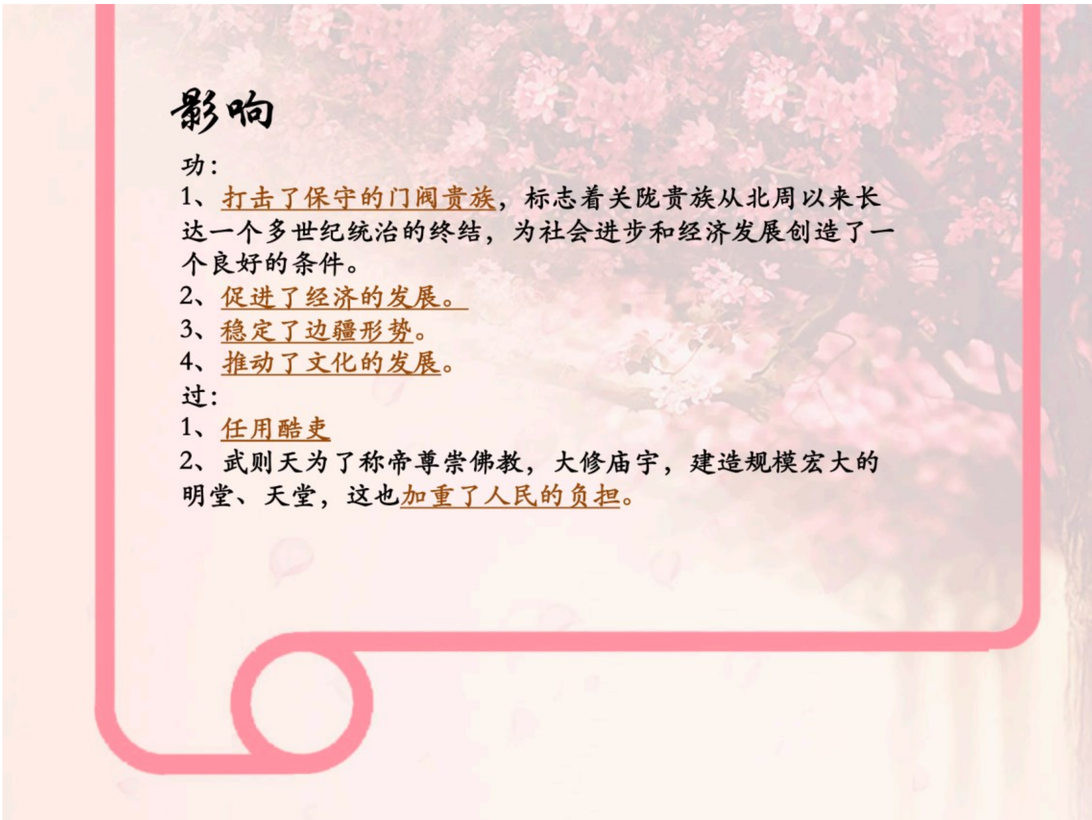
Map of her reign.



By spring 705, Wu Zetian was seriously ill again. Zhang Jianzhi, Jing Hui, and Yuan Shuji planned a coup to kill the Zhang brothers. They convinced the Generals Li Duozuo, Li Dan (李湛, note different character than the former emperor), and Yang Yuanyan (楊元琰), as well as chancellor Yao Yuanzhi to be involved. With agreement from Li Xian as well, they acted on 20 February, killing Zhang Yizhi and Zhang Changzong. They then had Changsheng Hall (長生殿), where Wu Zetian was residing, surrounded. They then reported to her that the Zhang brothers had been executed for treason, and they then forced her to yield the throne to Li Xian. On 21 February, an edict was issued in her name that made Li Xian regent, and on 22 February, an edict was issued in her name, passing the throne to Li Xian. On 23 February, Li Xian formally retook the throne, and the next day, Wu Zetian, under heavy guard, was moved to the subsidiary palace, Shangyang Palace (上陽宮), but was nevertheless honored with the title of Empress Regent Zetian Dasheng (則天大聖皇帝). On 3 March, the Tang dynasty was restored, ending the Zhou.



Zong Qinke, the son of Empress Dowager Wu's cousin, submitted a number of modified Chinese characters intended to showcase Empress Dowager Wu's greatness. She adopted them and took one of the modified characters, Zhao (曌), to be her formal name (i.e., the name on which the people would exercise naming taboo). Besides her own literary work, Wu Zetian’s court was a focus of literary creativity. Although Wu Zetian created Chinese characters for her political purposes, we can see her talent and extraordinary wisdom through these Chinese characters.



The influence of Wu:
Contribution:
1. Crackdown the conservative value of classes, which is a sign of the ending of the Guanlong noble group. Promoted the basic condition for the development of the society and economy.
2. Improved the development of economy.
3. Stabilized the condition of the frontier.
4. Promoted the development of literal and culture.
Negative:
1.Use cruel secret officers to deploy punishment.
2. In order to claim the emperor and respect Buddhism, Wu Zetian overhauled temples and built large-scale halls and heaven, which also increased the burden on the people.
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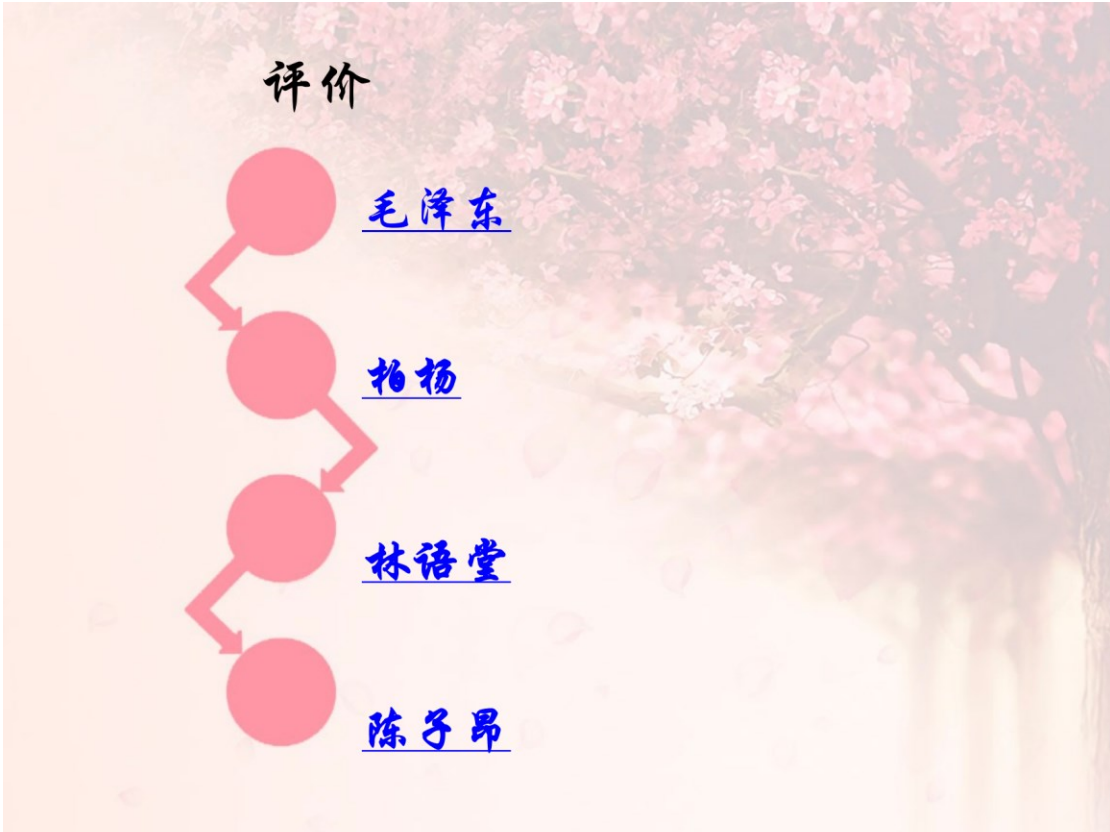

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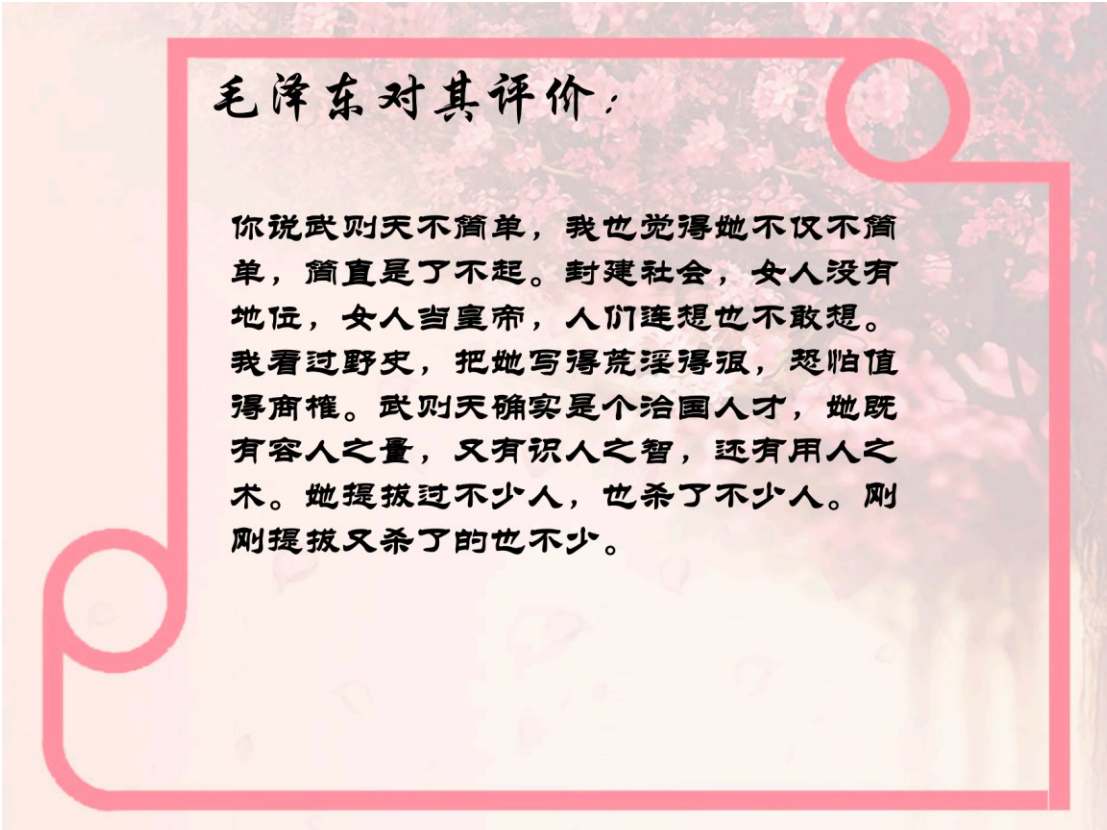
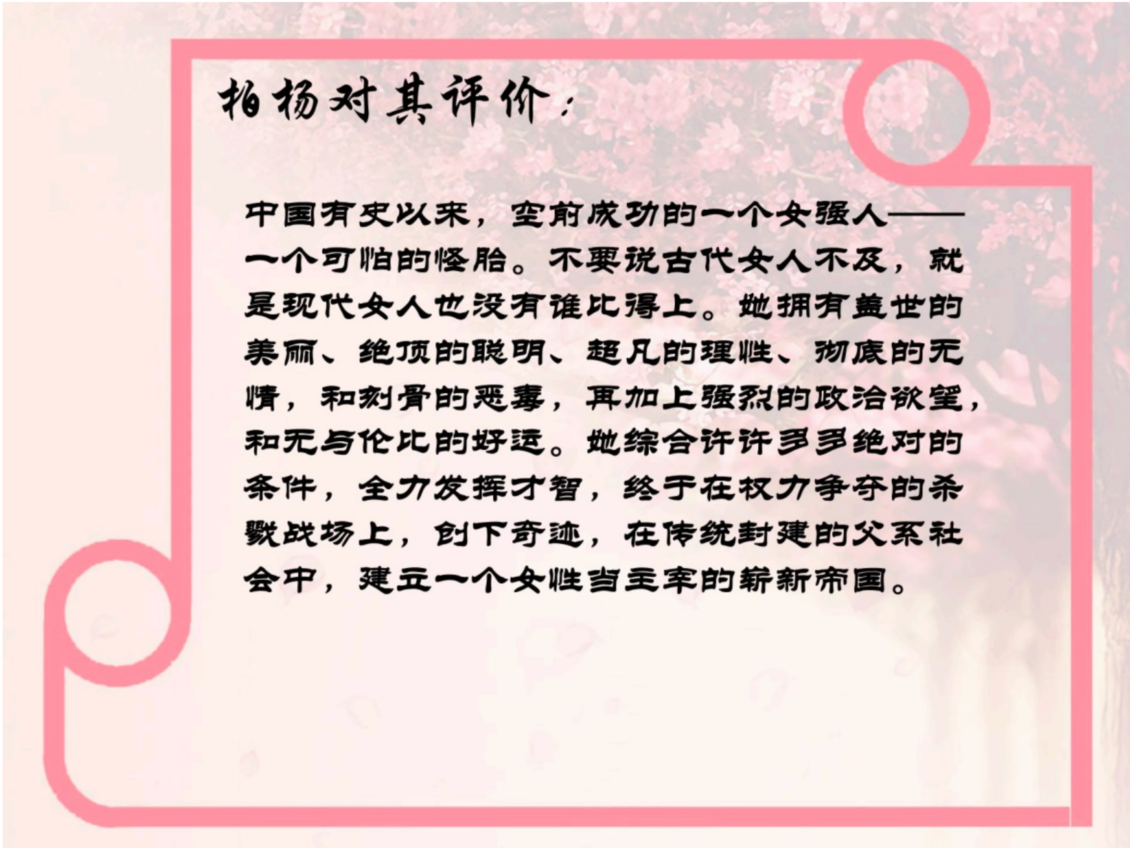
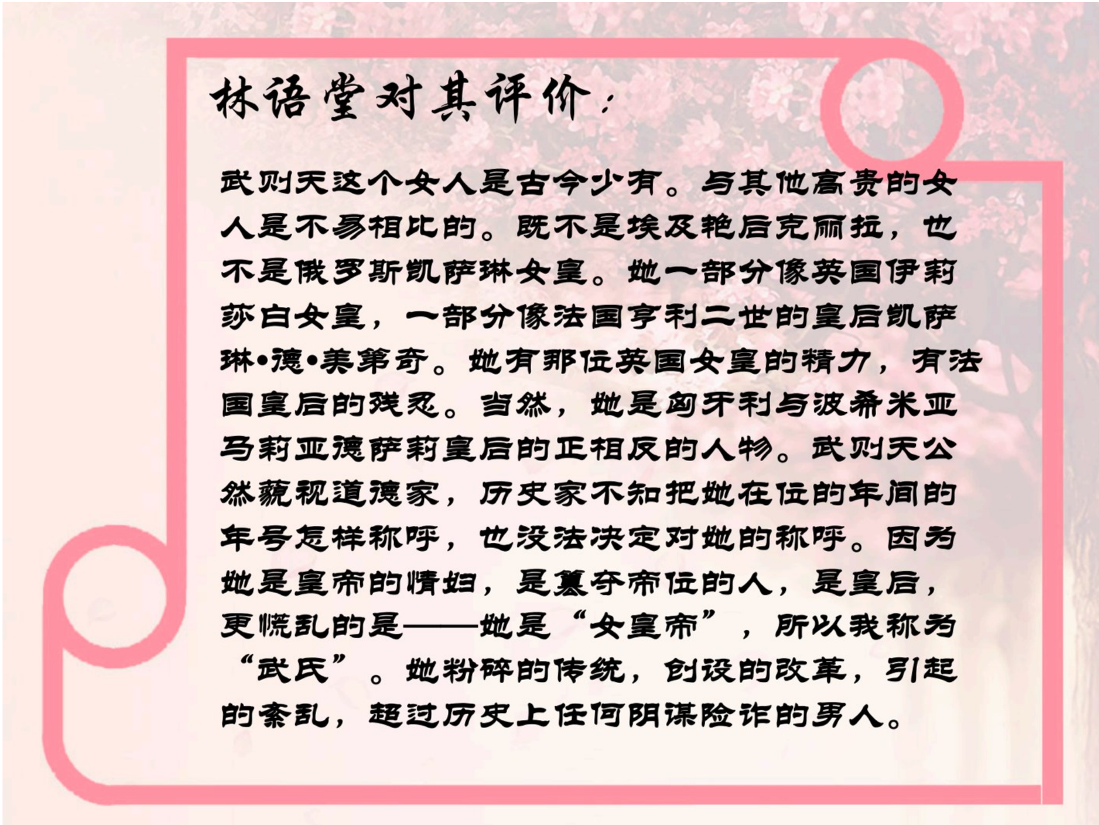
Comments and evaluations from others: Chairman Mao, Bai Yang, Lin Yutang, and Chen Ziang.



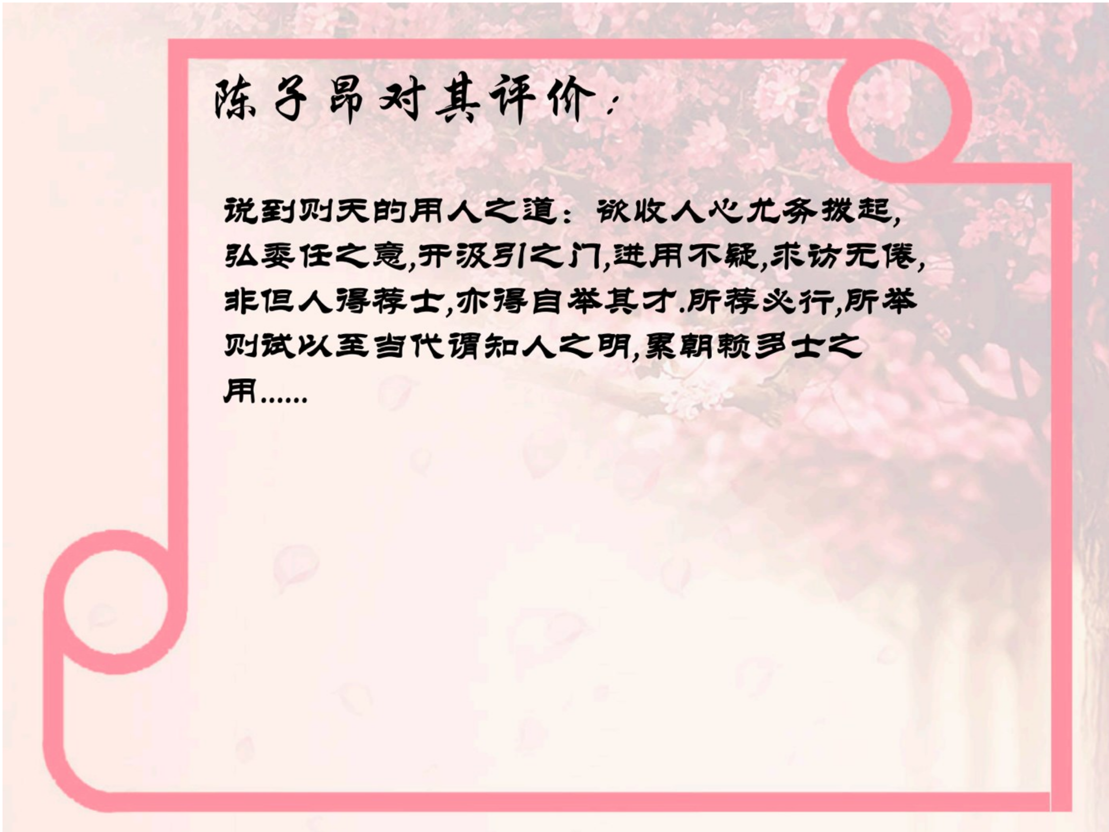
Chairman Mao's evaluation: Wu Zetian is not simple. I also think she is not only not simple but also is simply amazing. In a feudal society, women have no status, and people dare not even think about women being emperors. I have read the unofficial history and wrote her in a very debauched way. I am afraid it is debatable. Wu Zetian is indeed a talent for ruling the country. She has both the capacity to tolerate people, the wisdom to understand people, and the skill to use people. She has promoted many people and killed many people. There are a lot of people who have just been promoted and killed.



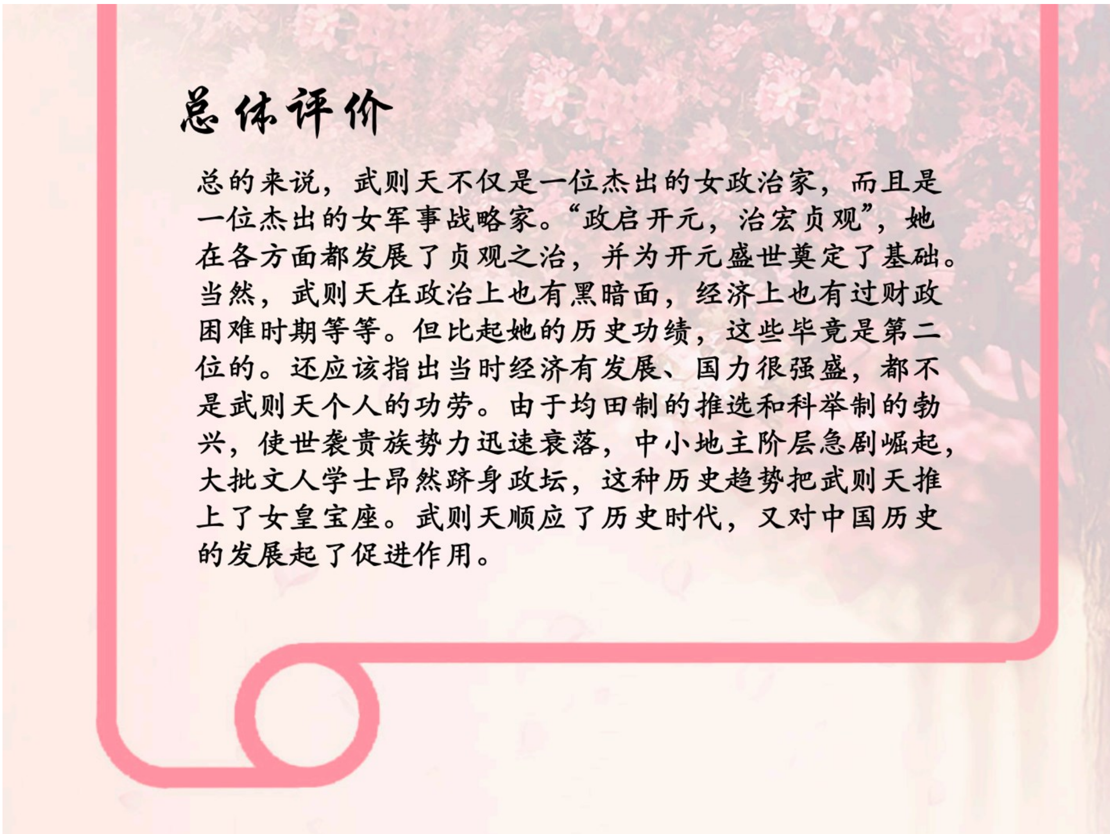
Bai Yang’s Evaluation: In the history of China, a strong woman with unprecedented success - a terrible freak. Don't say that ancient women are inferior. Even modern women are no match. She has unparalleled beauty, supreme intelligence, extraordinary rationality, utter ruthlessness, and bone-chilling viciousness, coupled with strong political desires and unparalleled good fortune. She synthesized many absolute conditions, exerted her talents with all her strength, and finally created a miracle in the slaughtering battlefield of power struggle. In the traditional feudal patriarchal society, she established a new empire dominated by women.



Lin Yutang’s Evaluation: Wu Zetian is a rare woman. It is not easy to compare with other noblewomen. Neither Cleopatra nor Queen Catherine of Russia. She is partly like Queen Elizabeth of England and partly Catherine de' Medici, Queen of Henry II of France. She has the energy of the Queen of England and the cruelty of the Queen of France. Of course, she is the exact opposite of the Hungarian and Bohemian Empress Maria de Sally. Wu Zetian blatantly despised moralists, and historians do not know what to call the years of her reign, nor can they decide what to call her. Because she is the emperor's mistress, the one who usurped the throne, the queen, and what's more frustrating is that she is the "female emperor", so I call it "Wu Shi". She shattered traditions, instituted reforms, and caused more disorder than any conspiratorial man in history.



Chen Ziang’s Evaluation: When it comes to Zetian's way of employing people: If you want to attract people's hearts, you must call on them, promote the meaning of the appointment, open the door to attract people, do not hesitate to use them, and ask for visits without fatigue. What you recommend must be done, what you do is tested, and even in the contemporary era, it is called the wisdom of knowing people.



The overall evaluation: To sum up, Wu Zetian is not only an outstanding female politician but also an outstanding female military strategist. She is the bridge between Zhenguan Golden Years and Kaiyuan Prosperous Age. She continuously developed all aspects of the Zhenguan Golden Years and essentially made the foundation of the Kaiyuan Prosperous Age. Wu Zetian also had her dark side in her politics. For example, there was a difficult time in the economy during her reign. But to compare with her contributions, they are the minor shortages. It should also be pointed out that the development of the economy and the national strength at that time were not the personal credit of Wu Zetian. Due to the election of the land-equalization system and the prosperity of the imperial examination system, the power of the hereditary aristocracy declined rapidly, the small and medium-sized landlord class rose sharply, and a large number of scholars and scholars entered the political arena proudly. This historical trend pushed Wu Zetian to the throne of the queen. Wu Zetian conformed to the historical era and played a role in promoting the development of Chinese history.

Appendix B

IRB Documentation

Parental Permission Form (Chinese)

DUQUESNE UNIVERSITY

600 FORBES AVENUE ¨ PITTSBURGH, PA 15282

家长知情同意书

题目:

自适应微学习：中国农村地区学生深度学习实证研究

谁负责此项研究？

刘婧韡

博士研究生，教育学院

liuj3@duq.edu
18792770777

导师

Misook Heo, 博士

教授

教育学院

heom@duq.edu

资源支持:

本研究是杜肯大学教育学院博士学位课题研究的实验部分

研究概况：

本研究预期有至少 80 名八年级的学生参与。

为什么进行本研究

您的孩子将被邀请参加一项研究，本研究旨在针对在线学习系统（教学元）的学习使用情况进行研究，以观察是否教学元学习系统是否能够提升学生的深度学习并作为高质量的课外辅助。教学元将记录和跟踪学生学习过程的投入度，并提供针对个性化需求的学习资源、学习活动与帮助。

为了使您的孩子获得更好的学习体验，请确保您的孩子已经是长安区中学八年级的学生。

我的孩子会被要求做什么？

您的孩子将被要求进行在线学习系统教学元的学习。学习过程大致 30 分钟，将在放学后根据您孩子的自主时间进行。在根据老师给到的登录信息登录教学元学习平台后，您的孩子将被询问年龄与性别。您的孩子将会被要求学习关于武则天的历史相关课程。在课前测试之后，将会被询问与课程内容相关的问题，查看整体学习框架，尝试不同的学习资源（视频、有声书、课件），以及参与不同的学习活动（如图片闪卡、连连看游戏、冒险拼图游戏、讨论版等）。在完成一系列学习活动之后，您的孩子将进行课后测试，之后会询问您的孩子关于教学元相关的学习体验。

除此之外，我们还询问您是否同意您的孩子接受我的采访。采访内容将被记录，但不会录音或录制。如果您的孩子接受采访，将会与我在腾讯会议上进行 30 分钟左右的一对一线上访谈。

这是唯一向您提出的请求。

这项研究的风险和好处是什么？

您的孩子参与本研究仅可能有极小的风险，但不会比日常生活中遇到的风险大。参与本项研究的直接好处是，您的孩子将有机会通过更加新颖、个性化的在线学习系统教学元回顾之前学习过的历史课程。间接的好处是，您的孩子将为学习分析研究做出贡献，有助于了解和改善学习成果的产出，特别是帮助中国农村地区孩子摆脱学习困境。

我的孩子参加这项研究会有报酬吗？

您的孩子参与本次参与本研究不会有任何补偿。参与这个项目不需要您或您的孩子支付任何费用。

保密性：

您的孩子在本研究中的参与（例如，教学元学习活动互动，包括对问题的回答，在学习活动上话费的时间，选择学习资源等）以及您的孩子提供的任何个人信息（如果您和您的孩子同意被纳入访谈环节，并且您的孩子成为受访者）在任何时候都讲尽可能地保密。

您孩子的名字绝不会出现在任何调查或研究工具上。所有书面和电子表格以及研究材料将被妥善保管，不会与您孩子的老师分享。在数据分析中不会出现任何身份信息。由于研究者将通过班级老师的帮助来确定受访者的身份，老师将知道受

访者的名字。但是，访谈的回答内容不会与班级老师分享。任何带有个人身份信息的研究材料在研究结束后将保存 5 年，之后销毁。

撤回的权利:

您没有义务允许您的孩子参加这项研究，您可以在任何时候通知您孩子的班主任，撤回您的许可。 您也可以选择将您孩子的数据完全从研究中撤回，或允许将收集到的任何数据用于最终的统计分析。

结果总结:

本研究的结果总结将根据要求免费提供给您。

数据的未来使用:

收集到的任何可以识别您或您的孩子的信息将不会用于未来的研究，也不会提供给除研究者及研究者导师以外的其他研究者。

自愿同意:

我已经阅读了上述声明，并理解对我和我孩子的要求。我也明白我孩子的参与是自愿的，我可以在任何时候、以任何理由撤回对我孩子的许可而不承担任何后果。

根据这些条款，我同意我愿意让我的孩子参加这个研究项目。

我明白，如果我对我的孩子参与本研究有任何进一步的问题，我可以联系刘婧韡 (liuj3@duq.edu, 18792770777). 如果我有关于保护人类主体研究的问题，我可以联系 David Delmonico 博士, 杜肯大学机构审查委员会主席, +011.412.396.1886 or delmonico@duq.edu.

如果您允许您的孩子参加次研究，您是否也允许您的孩子参加研究中的访谈部分？

_______ 是

_______ 否

____

孩子姓名

____

____

家长/监护人签名 日期

____

____

研究者签名 日期

Parental Permission (English Translation)

DUQUESNE UNIVERSITY

600 FORBES AVENUE ¨ PITTSBURGH, PA 15282

PARENTAL PERMISSION FORM

TITLE:

Adaptive microlearning: An empirical study among the students in the rural areas of China

WHO IS DOING THE RESEARCH?

Jingwei Liu
Doctoral Student, School of Education
liuj3@duq.edu
(+86)18792770777

ADVISOR: (if applicable)

Misook Heo, Ph.D.
Professor
School of Education
heom@duq.edu

SOURCE OF SUPPORT:

This study is being performed as partial fulfillment of the requirements for the doctoral degree in the School of Education at Duquesne University.

STUDY OVERVIEW:

This research study aims to examine how well an individualized online learning system (i.e., Teaching Cells) improves learning. The Teaching Cells system would be able to serve in the place of a quality tutor because the system can offer differentiated learning resources, activities, and assistance based on individual learners' interaction, progress, and performance within the system. As identifiable data is not collected, there would be limited risks associated with engaging in Teaching Cells. This research study expects a minimum of 80, 8^{th}-grade students as participants.

WHY IS THIS RESEARCH STUDY BEING DONE?

Your child is being asked to participate in a research project that seeks to investigate how well an individualized online learning system (i.e., Teaching Cells) promotes deeper learning as a good quality tutor might be able to. Teaching Cells tracks student engagement in learning activities and offers differentiated learning resources, activities, and helps. Please note that the research study is to evaluate the Teaching Cell, not your child's performance.

In order for your child to participate in this study, your child must be 8^{th}-grade in the Chang'an District Middle School.

WHAT WILL MY CHILD BE ASKED TO DO?

Your child will be asked to engage in learning via online Teaching Cell once, for about 30 minutes on their own time outside of school hours. Upon signing in the Teaching Cell using the login information provided by the classroom teacher, your child will indicate their age and biological sex. Your child will then be asked to respond to the questions about Empress Wu Zetian. Following the initial assessment, your child will have an opportunity to ask content-related questions, view the overall learning content structure, review diverse learning resources (e.g., video, audiobook, and presentation slides), and participate in a learning activity (e.g., picture cards, link game, trivia game, discussion). After completing this series of learning engagements, your child will be asked to respond to the questions about Empress Wu Zetian one more time. Before ending the interaction with Teaching Cell, your child will be asked to share a personal experience with the Teaching Cell.

In addition, if you allow me to interview your child, your child may be selected to participate in an online interview. If chosen for an interview, your child will meet with me online (via Tencent Meeting) for about 30 minutes and be asked to share the learning experience with and the perception of the Teaching Cell. All responses to the interview questions will be note-taken but will not be recorded.

These are the only requests that will be made of your child.

WHAT ARE THE RISKS AND BENEFITS OF THIS STUDY?

There are minimal risks associated with your child's participation but no greater than those encountered in everyday life. The direct benefit of participating in this research is that your child will have an opportunity to review a history lesson learned in the previous year via the novel, individualized online learning system, Teaching Cell. The indirect benefit is that your child will contribute to a learning analytics research, which help to understand and improve learning outcomes, especially for learners in the rural areas of China.

WILL MY CHILD BE PAID FOR TAKING PART IN THIS RESEARCH STUDY?

There will be no compensation for child's participation in this study. Participation in the project will require no monetary cost to you or your child.

CONFIDENTIALITY:

Your child's participation in this study (e.g., interaction with the Teaching Cell including responses to questions, time spent on task, chosen learning resources and activities) and any personal information your child provides (if you and your child agree to be included in an interview and your child is chosen as an interviewee) will be kept confidential at all times and to every extent possible.

Your child's name will never appear on any survey or research instruments. All written and electronic forms and study materials will be kept secure and will not be shared with your child's classroom teacher. No identity will be made in data analyses. The researcher will not know your child's identity, except the interviewees'. As the researcher will gain the help of classroom teachers in identifying the interviewees, the teachers will know the names of the interviewees. However, interview responses will not be shared with the classroom teachers. Any study materials with personal identifying information will be maintained for five years after the completion of the research and then destroyed.

RIGHT TO WITHDRAW:

You are under no obligation to give your permission for your child to participate in this study, and you may withdraw your permission at any time by notifying your child's classroom teacher. You may also choose your child's data completely withdrawn from the study or allow any data collected to be used in the final statistical analysis.

SUMMARY OF RESULTS:

A summary of the results of this research will be supplied to you, at no cost, upon request.

FUTURE USE OF DATA:

Any information collected that can identify you or your child will not be used for future research studies, nor will it be provided to other researchers other than the researcher's advisor.

VOLUNTARY CONSENT:

I have read the above statements and understand what is being requested of me and my child. I also understand that my child's participation is voluntary and that I am free to withdraw my permission for my child at any time, for any reason, without any consequences.

On these terms, I agree that I am willing to allow my child to participate in this research project.

I understand that should I have any further questions about my child's participation in this study, I may contact Jingwei Liu (liuj3@duq.edu, (+86)18792770777). Should I have questions regarding protection of human subject issues, I may contact Dr. David Delmonico, Chair of the Duquesne University Institutional Review Board, at (+01) 1.412.396.1886 or delmonico@duq.edu.

If you give permission for your child to participate in the study, do you also allow for your child to be included in the interview portion of the study?

_______ Yes

_______ No

____
Name of Child

______________________________ ________________
Parent / Legal Guardian's Signature Date

______________________________ ________________
Researcher's Signature Date

Assent Form (Chinese)

DUQUESNE UNIVERSITY

600 FORBES AVENUE ¨ PITTSBURGH, PA 15282

学生知情同意书

题目:

自适应微学习：中国农村地区学生深度学习实证研究

谁负责此项研究？

刘婧韡

博士研究生，教育学院

liuj3@duq.edu
18792770777

导师

Misook Heo, 博士

教授

教育学院

heom@duq.edu

研究人员为什么要做这项研究？

我要求你参与这项研究，使用一个新的学习系统（Teaching Cell），它可以帮助你更深入地思考和更好地学习。该系统很聪明，可以了解你需要学习更多的东西，以及如何更好地帮助你。我感兴趣的是你如何评价这个新的学习系统；而不是你的学习能力有多强。

为了参与研究，你必须是八年级，你的学校必须在长安区中学。

研究概况：

你必须做什么？

这项研究打算招募至少 80 名八年级学生作为参与者，调查教学元(Teaching Cell)的潜在用途。如果你参加这项研究，你将被要求在教学元中完成一些学习活动。你可以在放学后在家里完成这些活动。你的老师会给你登录信息和你的学生身份号码，以便加入教学元。登录后，你将需要首先回答一些关于你的年龄、性别和设备类型的问题。然后，你将参加一个关于去年所学的武则天历史知识的预先测试。在这些之后，你将被要求完成各种学习活动，你可以提出问题，查看整体学习内容结构，回顾多媒体材料，并享受学习游戏或讨论。在你完成所有的学习活动后，你将再次参加测试，问题可能相同或不同。然后，会有一个问卷调查，让你告诉我你对教学元的看法。

此外，如果你表示愿意参加后续的访谈，你可能会被选中进行在线访谈。如果你被选中，你将通过腾讯会议与我见面。我将问你一些关于你在教学元的经验和想法的问题。你的所有回答都会被记录下来，但不会被录音。

这些就是你需要做的全部。

这项研究学习需要多长时间？

根据你学习时的选择，你将在大约 20-30 分钟内完成教学单元。如果你选择更多的活动，将需要更多的时间，反之亦然。如果你被选中参加访谈，访谈环节将持续约 30 分钟。

这项研究的是否有害？好处是什么？

你参与这项研究并不比你生活中的其他事情更有害。如果有任何问题或步骤，你觉得不方便回答或执行，你可以不必这样做。
对你来说，参与本次研究直接的好处是你将获得一种新的有趣的在线学习方式。你将控制你的学习和学习过程。间接的好处是你的学习经验可以帮助研究者了解这种新的在线学习工具如何帮助提高学生的学习体验，特别是对于那些在农村地区辅导机会有限的学生。

如果有什么伤到了你，或者你对某些问题感到不舒服，请告诉研究者，我会停止或者尽我所能让你感觉好一点。

做这项研究你会有报酬吗？

你参加这项研究不会给你钱，但你的参与也不会让你付出任何代价。

其他人是否会知道你做了什么或说了什么？

我将对你在教学元（以及访谈，如果你被选中的话）中的所有回答保密。

如果我与其他人分享这个研究项目的任何信息，我绝不会说出你的名字，也不会在谈论你时让别人知道你是谁或你在研究中说了什么。你的老师永远不会知道你在教学元内回答了什么。如果你被选中参加访谈，你的老师会知道你被选中了，但绝不会知道你在访谈中说了什么。除了我的研究导师和我之外，没有任何人会知道你在研究期间做了什么或说了什么。所有收集到的数据将被保存五年，然后我将从我的电脑中删除它们。

如果你想退出，可以吗？

是的，如果你不愿意，你甚至不需要开始。 如果你开始后并决定停止参与，只要告诉研我或者你的老师就可以了。如果你决定停止，没有人会对你生气。 如果你决定停止，你可以让我知道你是否同意已经收集过的信息用于我的研究，这由你决定。

你能知道后来发生了什么吗？

如果你想知道我从这项研究中发现了什么，你可以要求我给你寄一份研究结果的副本。然后我将免费向你提供一份总结我的研究结果的论文。

我提供的信息将如何处理？

我不会收集任何识别信息，即人们可以找出你是谁（姓氏、地址等），所有收集的信息都将与系统生成的 ID 号码相关联。任何信息都不会被保留用于未来的相关研究，也不会被提供给除我和我的研究导师之外的其他研究人员。

好的，你愿意参与本项研究吗？

如果你阅读并理解了本同意书上的所有内容，并且明白如果你不愿意，你不必参加，而且可以随时退出，那么请在下面签上你的名字。这意味着你已经准备好参与。如果你还有问题，你可以向刘婧韡（liuj3@duq.edu，18792770777）咨询。如果你对自己在研究中受到的保护有疑问，那么最好的联系人是杜肯大学机构审查委员会主席 David Delmonico 博士，电话是(+01) 1.412.396.1886。

如果你愿意参加研究，你是否也愿意被纳入研究的访谈部分？

_______ 是

_______ 否

____
你的姓名

____ __________________
参与人签名 日期

____ __________________
研究者签名 日期

Assent Form (English Translation)

DUQUESNE UNIVERSITY

600 FORBES AVENUE ♦ PITTSBURGH, PA 15282

CHILD'S AGREEMENT TO PARTICIPATE IN A RESEARCH STUDY

TITLE:

Adaptive microlearning: An empirical study among the students in the rural areas of China

WHO IS DOING THE RESEARCH?

Jingwei Liu
Doctoral Student, School of Education
liuj3@duq.edu
(+86)18792770777

WHY ARE THE RESEARCHERS DOING THIS STUDY?

I am asking you to participate in this research study using a new learning system (Teaching Cell) that could help you think deeper and learn better. The system is smart to understand what you need to learn more and how to help you better. I am interested in how you evaluate this new learning system; not how good you are at learning.

In order to participate, you must be 8^{th} grade, and your school must be the Chang'an District Middle School.

STUDY OVERVIEW:

WHAT DO YOU HAVE TO DO?

This study intends to recruit a minimum of 80, 8^{th}-grade students as participants to investigate the potential use of Teaching Cell. If you participate in this study, you will be asked to finish several learning activities in the Teaching Cell. You may finish this after school at your home. Your teacher will give you login information and your ID number to join the Teaching Cell. Once signed in, you will need to first respond to some questions about your age, sex, and device type. You will then take a pre-test about the historical knowledge of Wu Zetian that you learned last year. After these, you will be asked to complete various learning activities, where you can ask questions, view the overall learning content structure, review multimedia materials, and enjoy a learning game or discussion. After you finish all the learning activities, you will take the test again with maybe the same or different questions. Then, there will be a survey for you to tell me about your thoughts on Teaching Cell.

In addition, if you indicate that you would like to be included in a potential interview, you may be selected to have an online interview. If you are chosen, you will meet with me via Tencent Meeting. I will ask you some questions about your experience with and thoughts on Teaching Cell. All your answers will be noted but not recorded.

These are all you need to do.

HOW LONG WILL YOU BE IN THE RESEARCH STUDY?

You will finish the Teaching Cell in about 20-30 minutes based on the choices you make while learning. If you choose more activities, it will take more time, vice-versa. If you are chosen for an interview, the interview session will last about 30 minutes.

IS THIS STUDY HARMFUL? HOW IS IT HELPFUL?

Your involvement in this study is not any more harmful than other things you do in your life. If there are any questions or steps that you do not feel comfortable answering or performing, you do not have to do so.

The direct benefit for you is that you will be exposed to a new fun way of learning online. You will control your study and learning process. The indirect benefit is your learning experience can help the researcher to understand how this new online learning tool could help student learning experiences, especially for those students in the rural area who have limited tutoring opportunities.

If anything hurts or you are uncomfortable with some of the questions, please feel free to stop answering the questions, quit the Teaching Cell activities, or ask to leave the interview.

WILL YOU GET PAID TO DO THIS STUDY?

There will be no money given to you for participating in this study, but your participation will also not cost you anything.

ARE OTHER PEOPLE GOING TO KNOW WHAT YOU DID OR SAID?

I will keep all you're your responses both in the Teaching Cell (and in the interview, if you are selected) confidential.

If I share any information from this research project with others, I will never give out your name or talk about you in a way that someone could figure out who you are or what you said in the research. Your teacher will never know what you have responded to within the Teaching Cell. If you are selected for an interview, your teacher will know that you were interviewed but will never know what you said during the interview. No one other than my research advisor and I will know what you have done or said during the research. All collected data will be kept for five years, and then I will delete them from my computer.

CAN YOU QUIT IF YOU WANT?

Yes. You do not even have to start if you do not want. If you do start and decide you do not want to do it anymore, just tell me or your classroom teacher know. No one will be mad at you if you decide to stop. If you decide to stop, you can let me know whether you wish your information that is already collected can be used for my research or not. It is up to you.

CAN YOU HEAR ABOUT WHAT HAPPENED?

If you want to know what I find out from this research study, you can ask me to send you a copy of the study findings. I will then provide a paper summarizing my study findings to you for free.

WHAT WILL HAPPEN TO THE INFORMATION I PROVIDE?

I will not collect any information from which people can figure out who you are. All the information collected will be associated with system-generated ID numbers. No information will be kept for use in future related studies, nor will it be provided to other researchers other than my research advisor and me.

OK, WOULD YOU LIKE TO DO IT?

If you read and understood everything on this assent form, and you understand that you do not have to participate if you do not want to, and can quit anytime you want, then please sign your name below. This means you are ready to participate. If you still have questions, you can ask Jingwei Liu (liuj3@duq.edu, (+86)18792770777). If you have questions regarding how you are protected in the study, then the best person to contact would be Dr. David Delmonico, Chair of the Duquesne University Institutional Review Board, at (+01) 1.412.396.1886.

If you would like to participate in the study, would you also like to be included in the interview portion of the study?

______ Yes

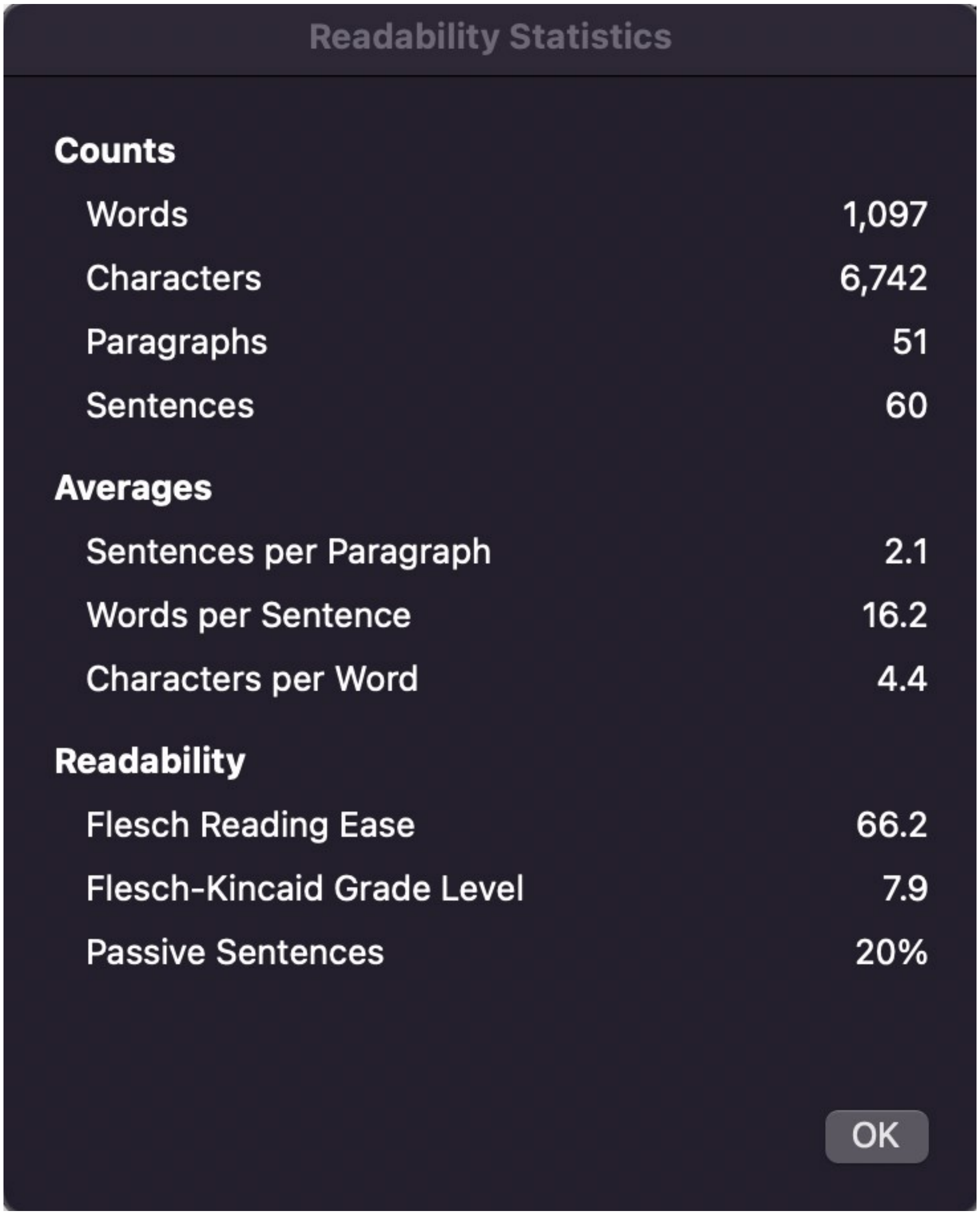
______ No

____ ________________

Participant's Signature Date

____ ________________

Researcher's Signature Date



Readability Statistics

Counts

Words	1,097
Characters	6,742
Paragraphs	51
Sentences	60

Averages

Sentences per Paragraph	2.1
Words per Sentence	16.2
Characters per Word	4.4

Readability

Flesch Reading Ease	66.2
Flesch-Kincaid Grade Level	7.9
Passive Sentences	20%

OK

A Screenshot of Tutorial Video

Transcript of Tutorial Video (English Translation)

Introduction

Hello everyone, thank you for your attention. My name is Viola Lui, and I am a student at Duquesne University in the United States. For my research study, I created Teaching Cell.

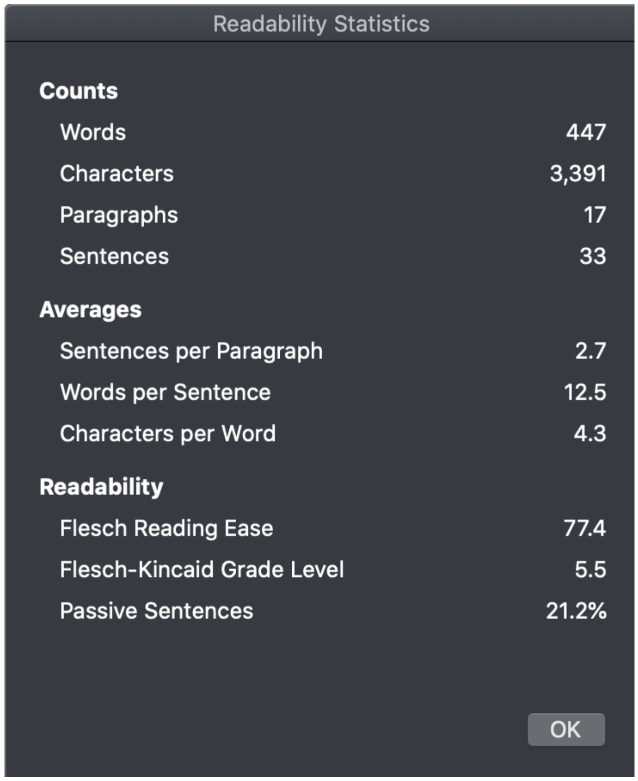
Teaching Cell is an online system where you can review the History of Empress Wu Zetian that you learned last year. Your teacher will send you the link to Teaching Cell and your ID.

Now, let me demonstrate to you how to access and use Teaching Cell.

1. Using your ID, sign in to Teaching Cell. You will be first asked to answer the demographic questions.
2. After the demographic questions, Teaching Cell will test how much you remember what you learned last year about Empress Wu Zetian.
   Please note that this test is not for your school. As Teaching Cell is for my research, your teachers will not see your answers.
3. Once you complete the test, you will be moved to the "ask question" section, You can choose any questions that match your interest.
4. You will then be presented with a map of the learning universe. Can you guess what other topic you would be interested in learning if you had an opportunity to learn with Teaching Cell? You will be asked to click on your chosen topic.

5. Now you will begin learning! You will be asked to choose your preferred learning resources. Upon completing reviewing your chosen resource, Teaching Cell will ask you the same choice question again so that you can choose additional learning resources. You can skip this choice question if you do not need any additional learning resources.
6. You will then be forwarded to fun exercises. You will be asked to choose your preferred exercise. You can try as many exercises as you wish to try out. You can choose to skip it if you do not need any additional exercises.
7. Once you complete your exercises, you will be asked to respond to the questions about Empress Wu Zetian. I remind you again that this test is not for your school, and your teachers will not see your answers.
8. Do you remember that I am a researcher? I will need your help at the end of your learning journey. You will be asked to share your Teaching Cell learning experiences with me. Please respond to the questions as honestly as possible.

You now know how to use Teaching Cell. Do you have the link to Teaching Cell? Do you have your ID? If so, go ahead and have a fun learning journey!


Readability Statistics
Counts
Words 447
Characters 3,391
Paragraphs 17
Sentences 33
Averages
Sentences per Paragraph 2.7
Words per Sentence 12.5
Characters per Word 4.3
Readability
Flesch Reading Ease 77.4
Flesch-Kincaid Grade Level 5.5
Passive Sentences 21.2%
OK

Question Bank (Chinese)

Table E1

课前测试与课后测试问题库

编号	问题	第一个错误选项	第一个错误选项解析	第二个错误选项	第二个错误选项解析	第三个错误选项	第三个错误选项解析	正确选项	正确选项解析
1	武则天继承的是哪个朝代?	玄宗（开元）。	玄宗的统治在武则天之后。	高宗	这实际上是武则天的丈夫的统治，与武则天一起开始了两个国王的时代。	中宗	这实际上是武则天的儿子的统治，他只统治了一年就被废了。	太宗（贞观）	太宗是贞观和武则天的第一任丈夫的时代。
2	武则天之后是哪个朝代?	太宗（贞观）	贞观之治实际上是在武则天的统治之前。	高宗	这实际上是武则天的丈夫的统治，与武则天一起开始了两个国王的时代。	睿宗	这实际上是武则天的儿子，他遵循了武则天的许多建议。	中宗	武则天的儿子，武则天死后，他回到宫中，成为下一任皇帝，尽管他只在位 5 年。

Table E1 (continued)

编号	问题	第一个错误选项	第一个错误选项解析	第二个错误选项	第二个错误选项解析	第三个错误选项	第三个错误选项解析	正确选项	正确选项解析
3	在武则天时期，哪些发展成就是真实发生的？	50 年来第一次增加税收。	实际上，在武则天时期，税收有所减少。	她恢复了渔业。	实际上，她参与了农业和商业，但没有具体参与渔业。	她坚持保留古老的权力传统。	实际上，她与旧的权力作斗争，发展新的领导方式，并纳入其他的声音。	农业和商业扩大了。	女皇武则天监督的社会是稳定的，农业、制造业和商业都得到了发展。
4	关于武则天，这些事实中哪些是真的？	武则天是中国的第三位皇后。	实际上，武则天是中国唯一的皇后。	武则天登基时只有十几岁。	实际上，武则天是登上皇位的最年长的皇后。	武则天被认为是弱者，她的丈夫更强大。	实际上，武则天被认为是中国历史上最强大的领导人之一。	她作为皇后统治了 15 年。	武则天确实统治了 15 年，从 690 年到 705 年。

Table E1 (continued)

编号	问题	第一个错误选项	第一个错误选项解析	第二个错误选项	第二个错误选项解析	第三个错误选项	第三个错误选项解析	正确选项	正确选项解析
5	这些事实中，哪一个是武则天功大于过的主要证据？	她领导国家使用经验考试制度来选拔人才。	武则天不是第一个使用实证考试制度的皇帝，因为这始于隋朝。	她取代了一个软弱多病的丈夫来统治政府。	这不是主要的证据，但这可能是她成功成为皇后的原因。	她重视人才，提倡聘用能力较强的人。	这不是主要证据，因为它只发生在武则天后来的执政中。	她在贞观和开元之间建立了〞桥梁〞。	修建这座桥是武则天在位期间产生的最重要影响。
6	武则天的第一任丈夫是谁？	高宗	高宗实际上是武则天的第二任丈夫，他也是太宗的儿子。	中宗	中宗实际上是武则天的儿子。	玄宗	玄宗实际上是吴国的孙子。	太宗	太宗是吴国的第一任丈夫，尽管他们并不浪漫。

Table E1 (continued)

编号	问题	第一个错误选项	第一个错误选项解析	第二个错误选项	第二个错误选项解析	第三个错误选项	第三个错误选项解析	正确选项	正确选项解析
7	武则天是什么时候成为皇帝并改变了统治名称的？	AD.637	吴氏于公元690年开始执政。公元637年，吴氏成为太宗的妻子。	AD.655	吴氏于公元690年开始执政。公元655年，吴氏成为高宗的皇后。	AD.674	吴氏于公元690年开始执政。公元674年，武则天开始在″二王″时代执政，但高宗仍是皇帝。	AD.690	武则天成为皇帝，在公元690年开始了她的周朝统治。
8	武则天在教育考试制度方面有什么创新？	她实施了经验性考试制度来选拔人才。	这种考试制度实际上开始于隋朝，也就是唐朝之前。	她扩大了考试科目的数量。	实际上，不是武则天而是太宗扩大了考试科目的数量。	她在考试中增加了诗词这一科目。	其实是玄宗在考试制度中增加了诗词，而不是武则天。	她在考试制度中增加了军事考试。	武则天将考试分为两部分，并在原来的纯文学考试制度中增加了新的军事考试。

Table E1 (continued)

编号	问题	第一个错误选项	第一个错误选项解析	第二个错误选项	第二个错误选项解析	第三个错误选项	第三个错误选项解析	正确选项	正确选项解析
9	武则天给她的统治起了什么名字？	唐	这是错误的，因为唐是武则天之前的统治者的名字。	武	武是武则天的姓氏，但不是她在位时的名字。	隋	这是错误的，因为隋朝的名字在唐朝之前。	周	当武则天成为皇后后，她从唐朝变成了周朝。
10	你认为武则天经历了什么样的环境？	分裂和社会动荡	这是错误的，因为在唐朝的早期，社会是稳定的、繁荣的、开放的。	经济上混乱	这是错误的，因为在唐朝的早期，社会是稳定的、适当的和开放的。	社会严格	这是错误的，因为在唐朝的早期，社会是稳定的、繁荣的、开放的。	繁荣和开放	在唐朝早期，社会是稳定的、繁荣的、开放的。
11	根据吴国的十二条建议，哪一条不是她的建议？	停止与其他国家的战争。	这是错误的，因为停止与其他国家的战争是她的建议之一。	禁止妓院和赌博。	这是错误的，因为禁止妓院和赌博是她的建议之一。	作为农民更有效地使用劳动者，而不是仆人。	这是错误的，因为更有效地使用劳动力是她的建议之一。	发展诗歌文化。	这是正确的，因为这在玄宗统治时期才发生。

Table E1 (continued)

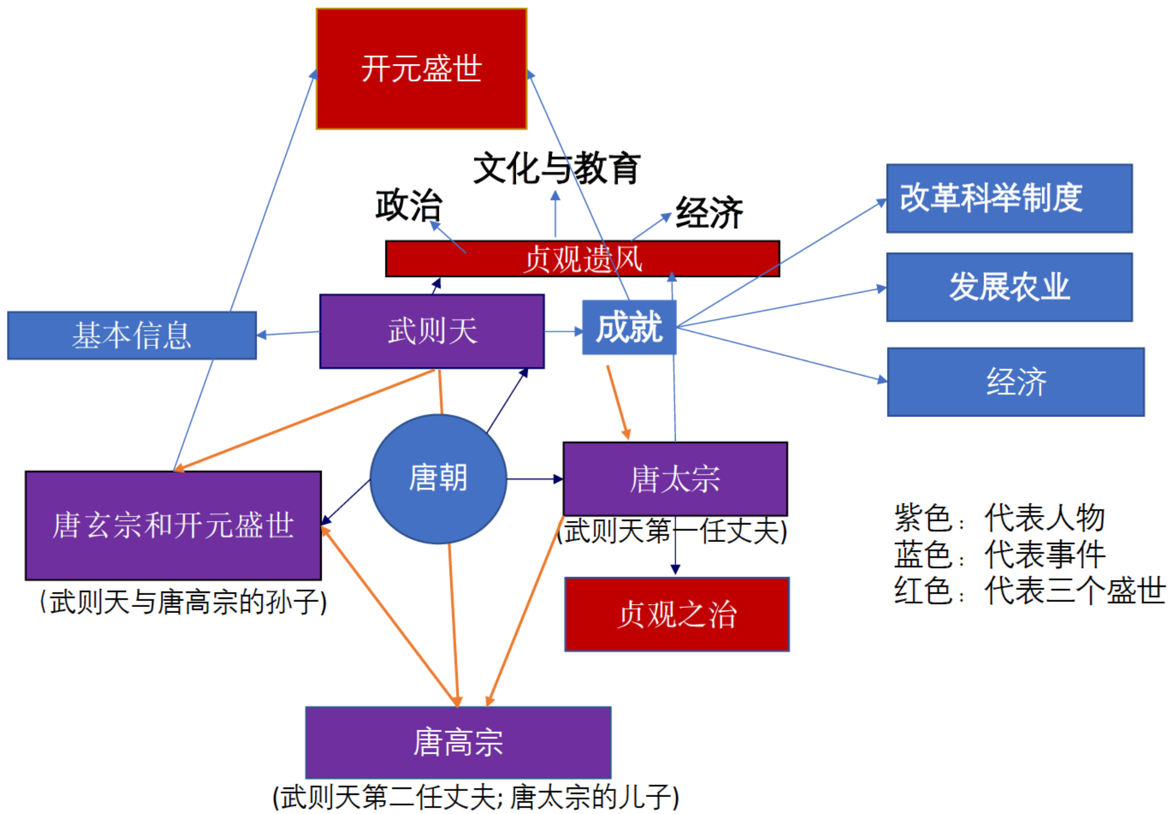
编号	问题	第一个错误选项	第一个错误选项解析	第二个错误选项	第二个错误选项解析	第三个错误选项	第三个错误选项解析	正确选项	正确选项解析
12	武则天在死前的名声如何？	极度富有和自私。	武则天晚年并不以富有和自私著称，而是以冷酷和残忍著称。	非常被动和嗜睡。	武则天晚年并不以被动或嗜睡而闻名，而是以冷酷和残忍而闻名。	非常有艺术性，注重美感。	武则天晚年不以艺术见长，而是以冷酷无情而闻名。	她以冷酷无情而闻名。	虽然在她统治的大部分时间里，她一直非常仁慈和慷慨，但随着她年龄的增长，她被指责为冷酷无情，尤其是对囚犯。

Ask Questions (Chinese)

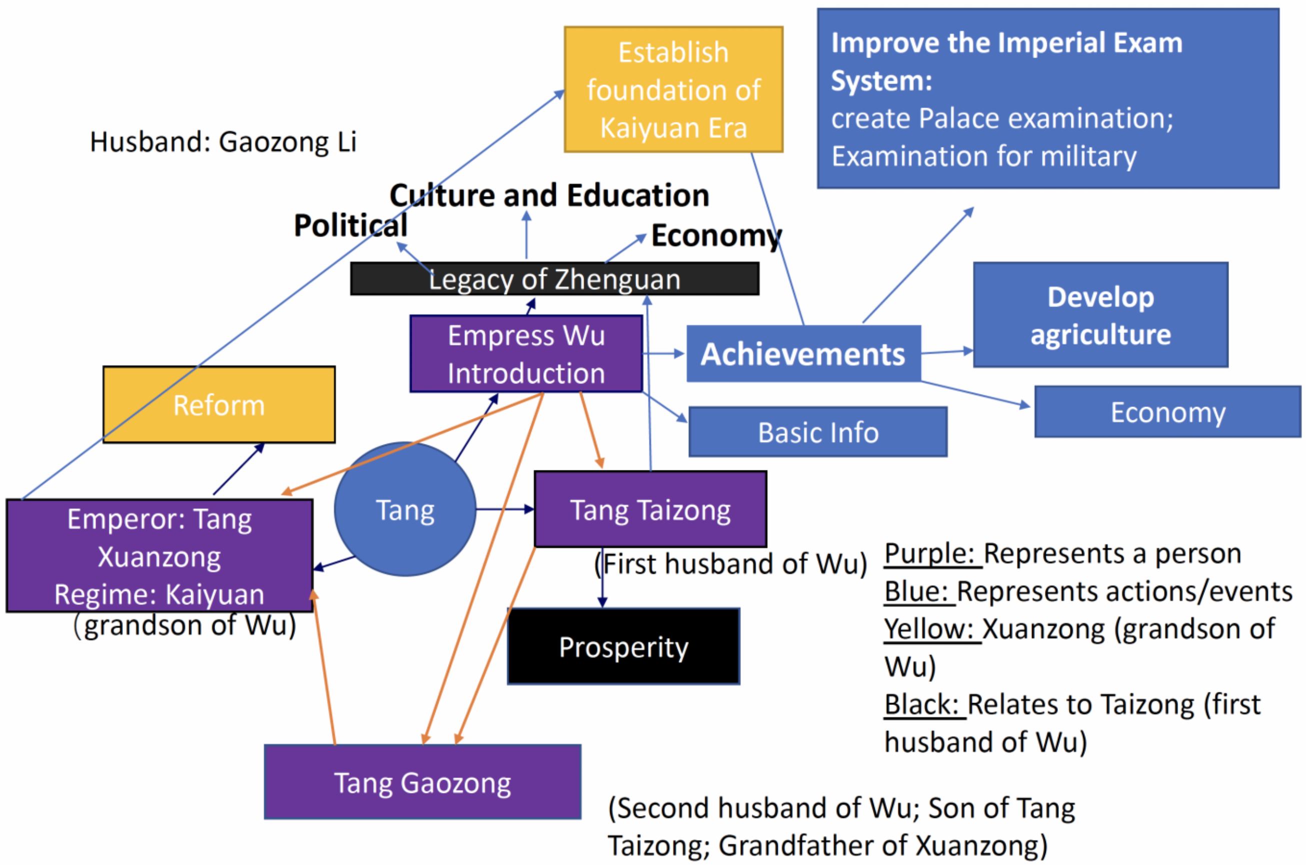
1. 武则天是中国历史上唯一的女皇帝吗？
2. 武则天在统治皇位多长时间？
3. 武则天统治时期的城市是什么样子的？
4. 在武则天统治时期发生了哪些发展？
5. 武则天是如何获得皇位的？
6. 武则天有宗教信仰吗？
7. 本教学元的其他学生对武则天有什么看法？
8. 武则天时代的物品是什么样子的？
9. 武则天与她的第一任丈夫结婚后历史上发生了哪些事件？
10. 你认为武则天的墓碑上没有字的原因是什么？
11. 武则天在位时的疆域图是什么样子的？
12. 武则天时期的皇宫时什么样子的？

Guidance (Chinese)

导学–中文版



Guidance (English Translation)

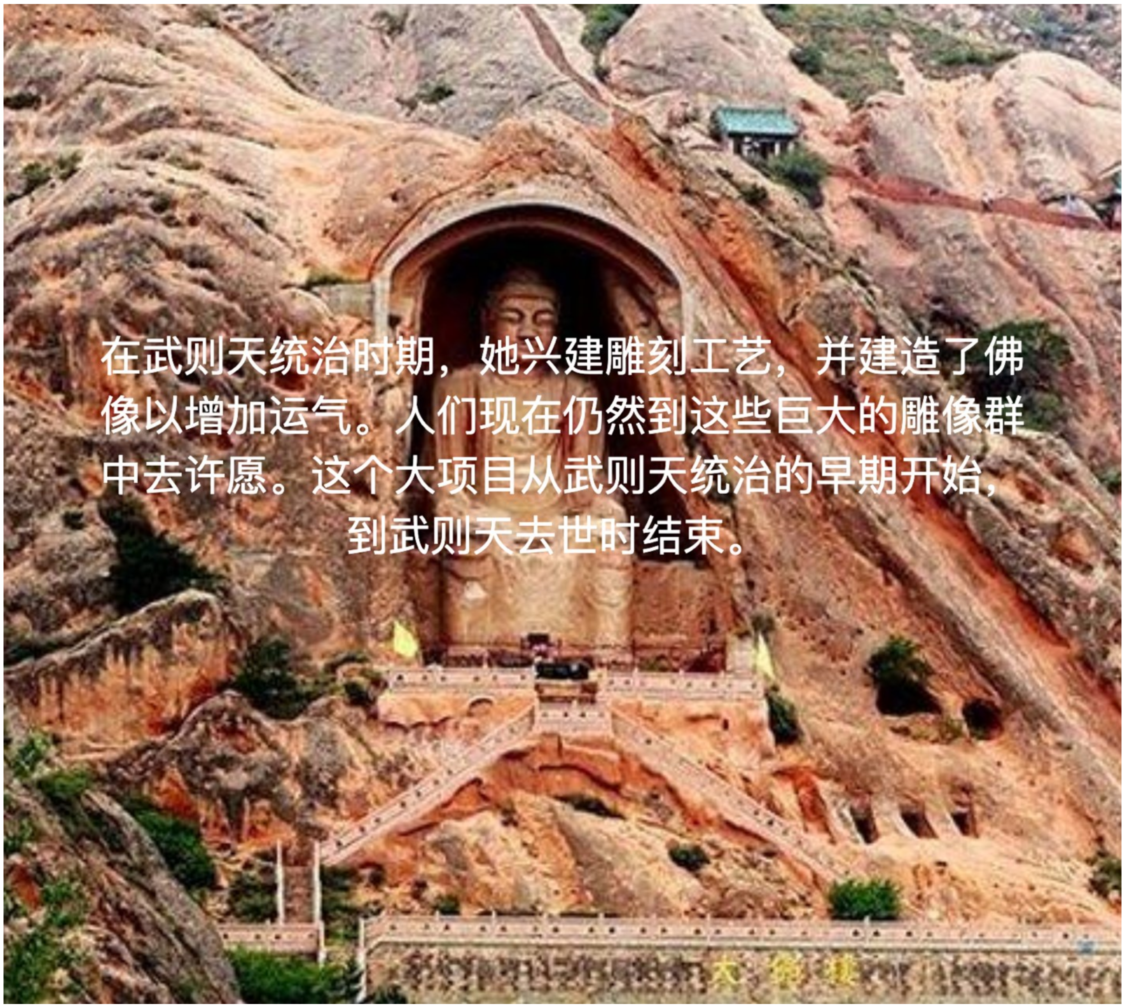


A Screenshot of Video Resource

Wu Zetian

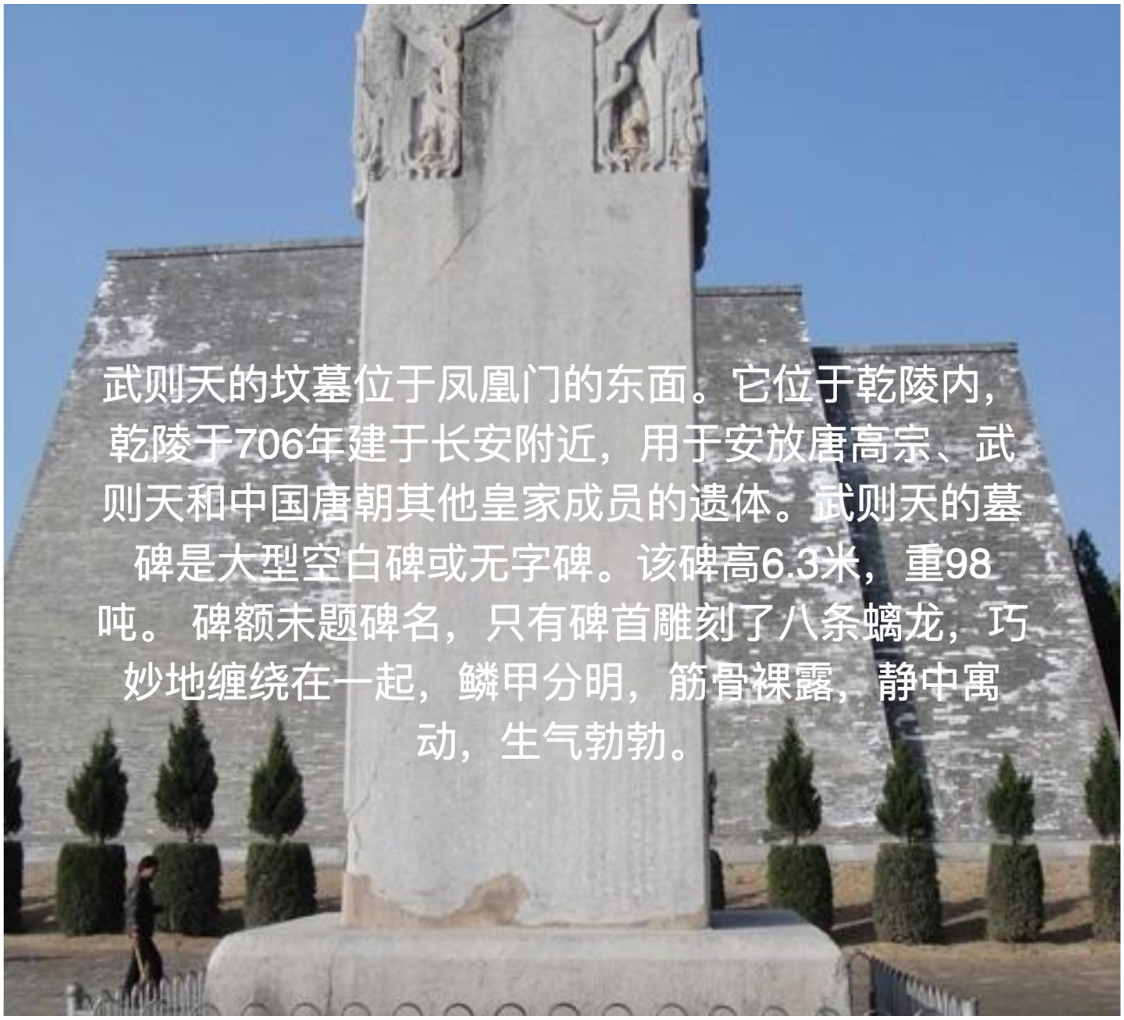
This is the sand table showing what Luoyang (the capital city of Wu's reign) looks like. It was called Ziwei City, the busiest and most flourishing city in the world at that time. The commerce and nightlife were very busy, and the population was very large. This is also the only city that was called "god city" because of its beauty and buildings.

This is Wu’s splendid palace. It still looks really beautiful because of ongoing maintenance.



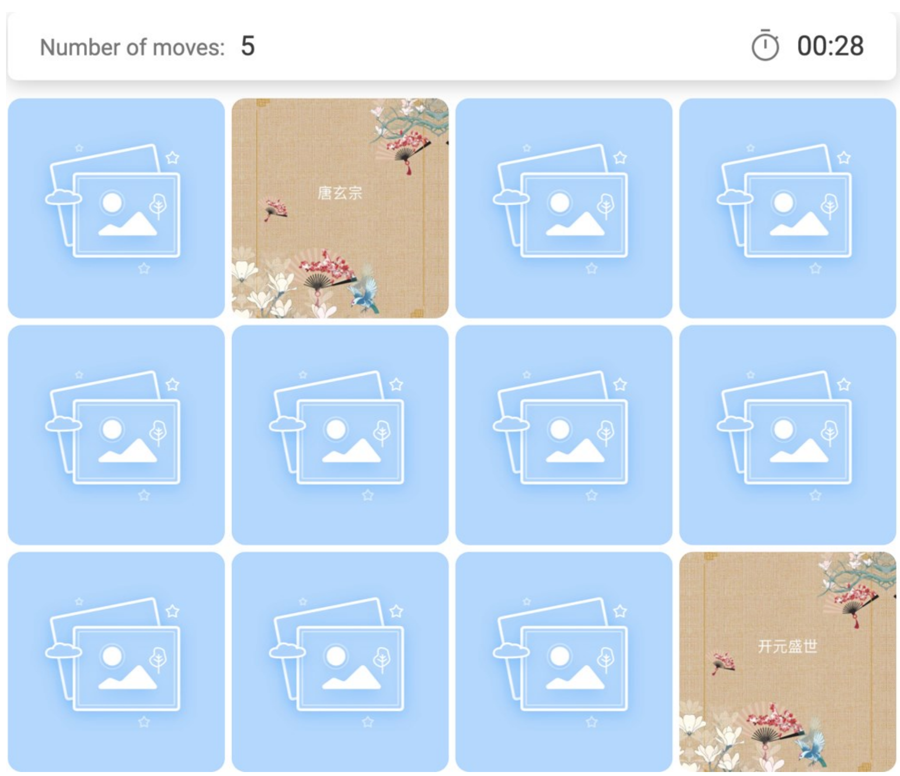
During Wu’s reign, she invested in carvings and built Buddha statues for more luck. People still go to these huge groups of statues to make wishes. This big project started in the early years of Wu’s reign and ended when Wu Zetian died.

Estimated territorial extent of Wu Zetian's empire.



Wu Zetian's tomb is located to the east of Phoenix Gate. It is within the Qianling Mausoleum, which was built near Chang'an in 706 to house the remains of Tang Gaozong, Empress Wu, and other royal members of the Chinese Tang Dynasty. It is the large Blank Tablet or Wordless Stele. This tablet is 6.3 meters tall and weighs 98 tons. It has no inscriptions, but the sides of the tablet have carved dragons, and the top has carved oysters.

A Screenshot of Link Game



Linked Cards

Link Game in Table

Order	First Choice	Second Choice
1	Wu Zetian became queen	AD 655
2	Gaozong	Wu Zetian's husband and son of Taizong
3	Wu's prime minister	Direnjie
4	Taizong	Zhenguanzhizhi
5	Starting Zhou reign	AD.690
6	Wu Zetian ended her reign	AD.705
7	The person as "bridge" between two prosperous reigns	Wuzetian
8	Xuanzong	Kaiyuanshengshi
9	Two kings ruling at the same time era	AD.664

There are 9 pairs of cards that could be linked to each other. Students will get the cards flipped if they get the correct match.

Jeopardy Game (Chinese)

冒险者游戏

顺序	主题	分数	危急问题	危险的正确答案
1	人物	100	武则天的第一任丈夫是谁？	太宗
2	人物	200	谁在高宗之后当了下一任皇帝？	中宗
3	人物	300	谁在二王时代执政？	高宗
4	人物	400	谁遵循了吴国的 12 条建议？	睿宗
5	事件	100	在吴国统治时期，哪些领域得到了发展？	农业、制造业和商业
6	事件	200	吴国统治时期的考试制度有什么创新之处？	增加了军事考试
7	事件	300	吴国的军事政策是什么？	停止与其他国家的战争
8	事件	400	哪个事件不属于吴国的统治？	人口减少
9	时间轴	100	吴国何时成为皇后？	AD.690
10	时间轴	200	吴氏何时成为高宗的皇后？	AD.655
11	时间轴	300	武则天何时得名 "武媚娘"？	AD.637
12	时间轴	400	两位国王的统治时期从何时开始？	AD.664

冒险者游戏介绍:

- 冒险者游戏共有三个游戏主题（历史人物游戏、历史事件游戏、历史时间线游戏）。
- 如果他们愿意，学生可以选择其中一种游戏主题或全部进行。
- 点击“开始”按钮，学生开始游戏。

• 在每场比赛中，有一个隐藏的图片，分为四个问题块。学生需要输入正确答案才能翻转并解锁隐藏图片的一部分。

• 在他们解锁隐藏图片的所有四个部分之后。学生会得到整个隐藏的图片，这张图片是课程的知识内容。

图 1 每个主题包含四个问题 （从易到难）

图 2 每个问题需要学生输入回答

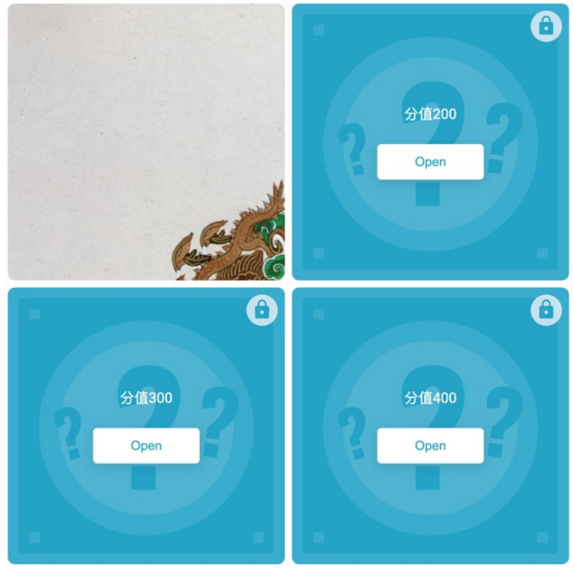


图3 每回答正确一个问题，可解锁一块拼图

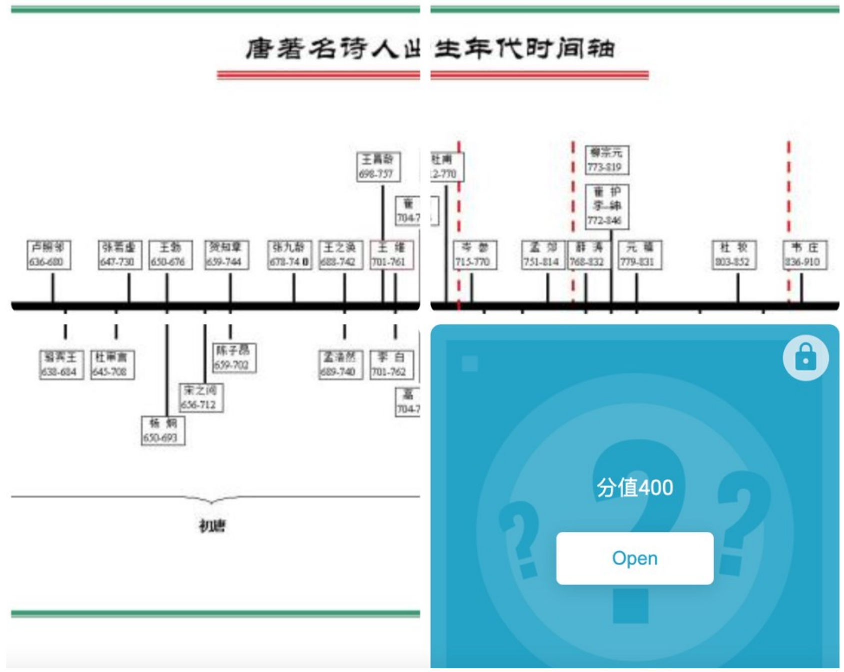


图 4 回答全部四个问题后解锁整个图，是本教学单元的知识点（如图，唐朝时间轴）

Jeopardy Game (English Translation)

Jeopardy Game in Table

Order	Theme	Points	Jeopardy Question	Jeopardy Correct Answer
1	Person	100	Who was Wu Zetian's first husband?	Taizong
2	Person	200	Who came after Gaozong as next emperor?	Zhongzong
3	Person	300	Who ruled during the two king era?	Gaozong
4	Person	400	Who followed Wu's 12 suggestions?	Ruizong
5	Event	100	Which areas were developed during Wu's reign?	Agriculture, manufacturing and business
6	Event	200	What was the innovation of the exam system during Wu's reign?	Added military examination
7	Event	300	Which was Wu's military policy?	Stop the war with the other kingdom
8	Event	400	Which event does not belong to Wu's reign?	The population decreased
9	Timeline	100	When did Wu became the empress?	AD.690
10	Timeline	200	When did Wu became the queen of Gaozong?	AD.655
11	Timeline	300	When did Wu got name "Wumei"?	AD.637
12	Timeline	400	When two king ruling period start?	AD.664

Introduction manual for Jeopardy Game:

- The Jeopardy game has three game themes in total (historical characters, historical events, and historical timeline).
- Students could choose one of the game themes or do all of them if they would like to.
- Students will start the game by clicking the “start” button.
- In each game, there is one hidden picture that is divided into four question blocks. Students need to type in the correct answer to flip and unlock one part of the hidden picture.
- After students unlock all four parts of the hidden picture, they will get the whole hidden picture. This hidden picture offers interesting and extra knowledge of Wu Zetian.

Figure 1 Four questions with different points (easy to difficult)

Figure 2 Answer the question from each square

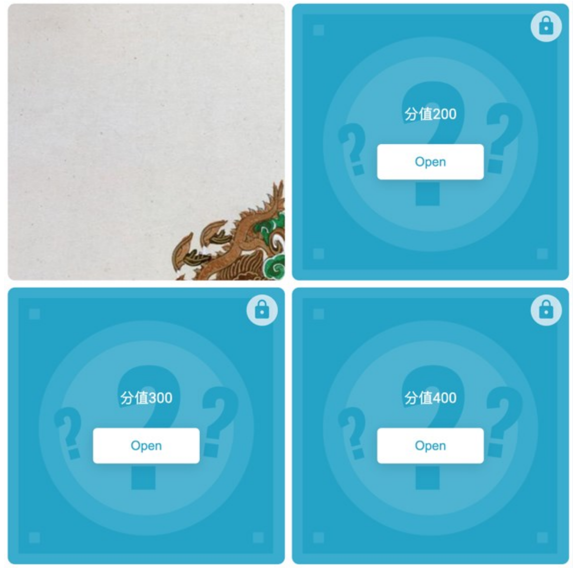


Figure 3 Unlock the block with correct answer

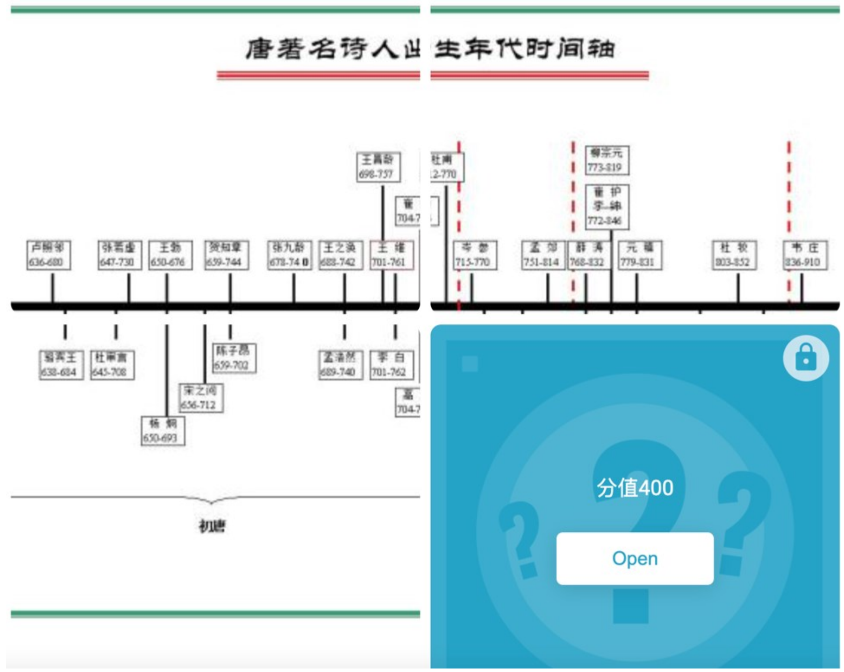
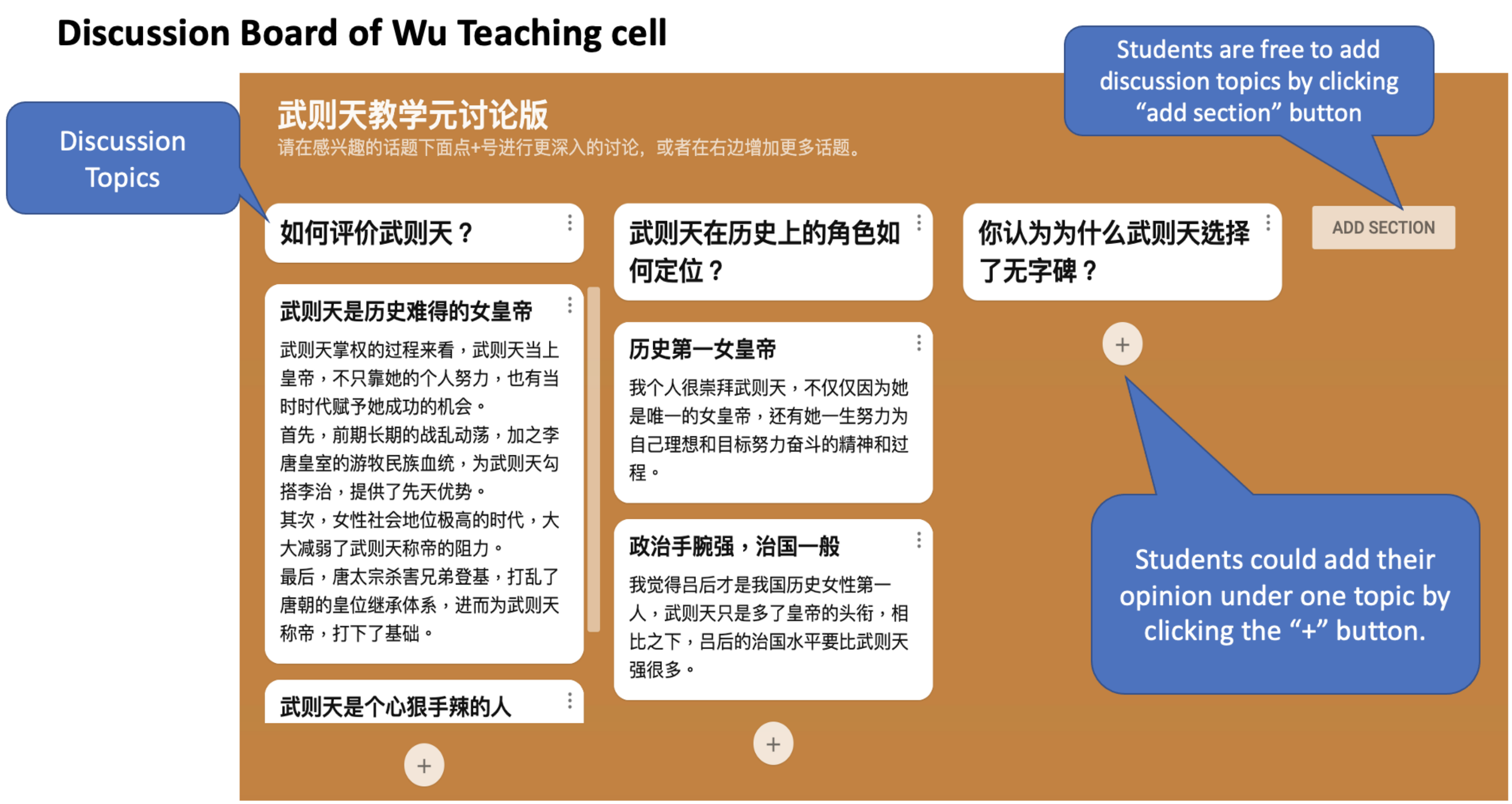


Figure 4 Unlock all block to receive hidden picture with knowledge point (Timeline of Wu Zetian)

Discussion Board Application



Evaluation Questions (Chinese)

李克特量表评价内容

请对你刚刚完成的课程进行评价：非常不同意，比较不同意，不确定，比较同意，非常同意

顺序	说明
1	教学单元很容易浏览。
2	我能够在教学元学习平台中很快找到我想找的内容和按键。
3	教学元中不同项目的功能是很直观和简便的。
4	我在使用教学元平台学习时没有任何技术问题。
5	我在使用教学元平台时遇到困难。
6	我成功地在不同的设备上使用教学元（笔记本电脑、iPad、智能手机）。
7	教学元中的学习材料对我来说是很贴近现实的。
8	教学元的学习结果与我的实际生活经验有关。
9	在教学元的学习中，我学到了解决现实问题的综合思考方法。
10	通过教学元平台，我学会了如何为学习内容寻找准确的支持材料。
11	教学元可以让我使用不同类型的学习材料和学习方法。
12	教学元让我跳过我已经知道的内容以节省我的学习时间。
13	教学元让我选择我感兴趣的学习活动，使学习更加有趣。
14	我可以在教学元中加入自己的想法。
15	我觉得教学元的学习材料很有吸引力。
16	我在使用教学元学习后，做测试时感到很有信心。
17	我觉得教学元的学习材料对我来说有一定的挑战性（不是简单无聊的）。
18	我感到被鼓励在教学元中分享我的想法。
19	我感到被鼓励在教学元中提出问题。
20	我觉得教学单元允许我控制自己的学习进度，没有任何压力。

Evaluation Questions (English Translation)

Please evaluate the course you have done: Strongly disagree, somewhat disagree, not sure, somewhat agree, strongly agree.

Order	Statement
1	The teaching cell was easy to navigate.
2	I was able to find everything I was looking for in the teaching cell.
3	The function of the different items in the teaching cell was intuitive.
4	I had no technological problems using the teaching cell with my technology.
5	I had trouble accessing the teaching cell.
6	I was successful using the teaching cell on different technology tools (Laptop, iPad, Smartphone).
7	The learning materials in the teaching cell are authentic to me.
8	The learning result from the teaching cell could relate to my real life experiences.
9	I learned realistic ways to synthesize and think during teaching cell learning.
10	I learned how to find evidence for the accuracy of the learning contents.
11	The teaching cell offers me ways to learn using different types learning materials.
12	The teaching cell let me skip what I already knew to save my learning time.
13	The teaching cell allows me to choose the learning activities that interest me to make learning more fun.
14	I could add my own ideas into the teaching cell.
15	I feel learning materials in the teaching cell are very engaging.
16	I felt confident when I did the test after learning using the teaching cell.
17	I feel the teaching cell's learning materials are at the right level of challenge for me.
18	I feel encouraged to share my ideas in the teaching cell.
19	I feel encouraged to ask questions in the teaching cell.
20	I feel the teaching cell allows me to control the pace of my learning without any pressure.

Interview Questions (Chinese)

1. 你使用教学元的总体体验是什么？
2. 您最喜欢的部分是什么，为什么？
3. 你最不喜欢的部分是什么，为什么？
4. 你认为 教学元的哪一部分对你帮助很大？
5. 与其他教学技术相比，你认为教学元最吸引你的是什么？
6. 作为一个潜在的用户，你有什么建议或意见吗？

Email to Teachers (Chinese)

尊敬的老师您好，

谢谢您同意帮助我进行研究。你可能记得，我叫刘婧韡，是美国杜肯大学的博士生。目前，我正在进行我的论文研究，关于在线适应性微学习对中国学生提高深度学习的有效性。我相信学生将取得更高的学习成果，并建立必要的能力，帮助他们在毕业后成功掌握 21 世纪的技能。此外，这项研究还将有助于缓解中国农村和城市地区之间的资源不平衡问题。本课题需要收集中国学生在新开发的自适应微课学习平台上针对一节样本课学习的体验和效果信息。我们邀请您的学生参加此样本课程的学习。时间约为 30 分钟。

我需要您帮助我招募八年级的学生，让他们参加我的研究性学习，他们将参与在线学习。学习内容为七年级人教版历史第二册第二单元的 "唐朝历史"。参与时间约为 30 分钟。

我很高兴与您见面并进一步讨论期望您做的事情。我的诉求主要有以下几点。

- 将所附的招募传单、家长同意书和儿童同意书寄到你的学生家里。
- 收集返回的表格
- 填写参与人名单（附 Excel 文件）
- 将研究的 URL 和学生分配的研究 ID 分享给那些交回两份表格的人
- 与交回两份表格的人分享介绍的操作视频
- 在删除任何个人身份识别信息（如参与者的姓名）后，与我分享参与者名单的副本。

一旦研究的学习部分完成，我将要求你提供三个被选中的参与者的联系信息，以便进行深入访谈。我将向你提供他们的学习 ID。

非常感谢您的参与与支持！

刘婧韡
Liuj3@duq.edu
联系电话：18792770777

Email to Teachers (English Translation)

Dear Teacher,

Thank you for agreeing to help with my research study. As you may remember, my name is Jingwei Liu, a doctoral student at Duquesne University, USA. Currently, I am conducting my dissertation research regarding the effectiveness of online adaptive microlearning for students in China to enhance deeper learning. I believe students will achieve higher learning outcomes and establish the capabilities essential to help them succeed with 21st-century skills after they graduate. In addition, this research will also help mitigate the unbalanced resource between rural and urban areas in China.

I need your help recruiting 8th-grade students who will participate in my research study where they will engage in online learning. The learning content regards Unit 2 of "Tang Dynasty history" in the second volume of the 7th-grade history of human education. The participation will last approximately 30 minutes.

I am happy to meet with you and further discuss what is expected of you. Mainly, I am asking the followings:

- Sending the attached recruitment flyer, parent permission form, and child assent form to your students' homes
- Collect the returned forms
- Fill in the participant list (attached Excel file)
- Share the research URL and study IDs to those who returned both forms
- Share the introductory how-to video with those who returned both forms
- Share a copy of the participant list with me after removing any identifiers (e.g., names of the participants)

Once the learning part of the study is complete, I will ask you for the contact information of the three chosen participants for an in-depth interview. I will provide you with their study IDs.

Thank you for your help!

Sincerely,

Jingwei Liu
liuj3@duq.edu
Phone: +86 18792770777

Recruitment Flyer (Chinese)

你想体验创新的在线个性化学习吗？

你被提供这些信息是因为你的学校和老师选择参与一项教育研究（自适应微学习：在中国农村地区学生中的实证研究）。

- 这项研究考察了一个创新的自适应微学习系统，名为教学元，旨在为中国农村地区的学生提供高质量的课外学习机会。
- 教学元提供个性化的学习，自动适应每个学习者。
- 教学元为学生提供了刷新他们去年学习成果的机会。
- 你将有机会对教学元进行评估。
- 请注意，这项研究的目的是评估教学元，而不是你。因此，任课教师将无法获得在教学元内收集的数据。

欢迎加入本项研究！

研究者：

刘婧韡
liuj3@duq.edu
+86 18792770777

Recruitment Flyer (English Translation)

Would you like to experience innovative online individualized learning?

You are being provided this information because your school and teacher chose to participate in educational research (*Adaptive Microlearning: An Empirical Study Among the Students in the Rural Areas of China*).

- The research study examines an innovative adaptive microlearning system called **Teaching Cell,** designed to offer quality out-of-classroom learning opportunities to students from rural areas of China.
- **Teaching Cell** offers individualized learning, automatically adapted to individual learners.
- **Teaching Cell** offers students the opportunity to refresh their learning from last year.
- You will have opportunity to evaluate **Teaching Cell**.
- Note that the goal of the research study is to evaluate the Teaching Cell, not you. As such, classroom teachers will not have access to the data collected within the Teaching Cell.

Join the research study!

Researcher:

Jingwei Liu
liuj3@duq.edu
617-755-0868

Appendix C

Interview Questions

1. What are your overall experiences of using Teaching Cell?
2. What is most favorite part, and why?
3. What is your least favorite part, and why?
4. Which part do you think Teaching Cell helped you a lot?
5. To compare with other teaching technology, what do you think Teaching Cell attract you the most?
6. Do you have any suggestions or advice as a potential user?

Appendix D

English Transcriptions of Chinese Interviews

Abbreviations: V = Viola (doctoral student, interviewer). S = Student interviewee (each identified S1, S2, and S3, for total n=3).

S1 Transcript

V: Hi, it's very nice to have you for our interview today. Let's talk about the first question. May I know your overall experiences with the Teaching Cell? For example, which part did you think was more interesting, or which part was very new to you, or which part did you think is confusing?

S1: I think the most impressive part is the Guidance. It made me feel very clear about what I need to learn in a whole picture. And also, the Teaching Cell will be based on your interests to target your learning. It's very nice.

V: Thanks for your answer. Is there anything you think that's not good? Or needs to be improved?

S1: Yes, the whole process is a little bit confusing, in that sometimes, I don't know which button I should use.

V: Do you mean the User Interface Design?

S1: Yes, the buttons.

V: Okay, because I am doing my doctoral research, this is only a prototype, and so it was established on a survey platform which may cause some confusion. I will make it as a real product afterward. Then, do you think if this becomes a real product, will you use it to help with your learning? There will be many subjects.

S1: Yes, I am sure I will use it. I think the Teaching Cell is very useful for preview and review.

V: Okay. Thank you. I know there are many learning apps and platforms in China now. To compare with other teaching technology, what do you think about the Teaching Cell attracts you the most?

S1: I think the Teaching Cell has more logical frames that could help me make a better connection among the knowledge [in the app]. And because of the new policy, we don't go out for tutors anymore. But we would like to learn more related knowledge besides the textbook. The Teaching Cell provided much related knowledge [like an] extra curriculum, and I found much knowledge that I interested me, that was never shown in the textbook.

V: This is what I am doing this for, to cause you to have learning deeper with more related knowledge, and make learning more personalized to improve your learning motivation and results.

S1: I can feel it [the Teaching Cell] could do it.

V: Thank you! Are there any suggestions besides the UI design?

S1: The teaching format is very clear, if you are providing this platform to younger kids, maybe adding more games or some fun stuff would be better.

V: That's a good suggestion! Thank you very much!

S2 Transcript

V: Hi, it's very nice to have you for our interview today! I have prepared a list of questions. Could we start with these one by one?

S2: Sure.

V: Thank you! Okay, may I know your overall experience from you using the Teaching Cell?

S2: My overall experience is I feel improvement of my logical and cognitive capabilities by using the Teaching Cell. I feel I could find a better and more suitable learning method for my learning, and it can help me learn better in the classroom, too.

V: Wow, that's so nice to hear! How about question 2, what is your favorite part [of the Teaching Cell] and why?

S2: My favorite parts are the fun exercises. These are very interesting! Another part I liked is the content of Teaching Cell because it is extending the knowledge, which helps me learn more than textbook, and is more fun!

V: So nice to hear that! How about the least favorite part? And why?

S2: I am not a fan of the discussion group. Because if we can't organize it very well, it will be a lot of chaos, and interrupt our learning.

V: Do you mean the discussion board?

S2: Yes.

V: Okay. Thank you for your input. Then, which part of the Teaching Cell do you think helped you a lot?

S2: It's very intelligent, and could help me focus on my own learning strengths and weaknesses. It may help me from the ability to preview to review the lessons.

V: Yes. That's what Teaching Cell is intended to do! I know there are many technological learning apps and platforms in China. To compare with other teaching technology, what do you think about the Teaching Cell attracts you the most?

S2: Teaching Cell is very personalized. Most of our learning apps are the same content, just different stages, or lessons. So the Teaching Cell could make more targeted learning for us to make learning easier.

V: Nice! After my graduate, I will make the Teaching Cell a real product. May I know if you have any suggestions or advice as a potential user?

S2: I wish there will be a conversation function that allows students to communicate with each other or with a counselor. It will be a big help for us.

V: That's a good suggestion! Thank you very much!

S3 Transcript

V: Hi, it's very nice to have you for our interview today! I have prepared a list of questions. Could we start with these one by one?

S3: Yes.

V: Thank you! Ok, may I know your overall experience from using Teaching Cell?

S3: The Teaching Cell is very new to me. I never tried learning platforms like this.

V: Oh, do you mean a good "new" or bad "new"?

S3: A good one. But also, I feel a little bit confused also because of it being new.

V: Got it. We could talk more in the later questions. How about question 2, what is your favorite part and why?

S3: My favorite part is I can choose from everything. I can choose what to learn, and I have a chance to skip. We are always asked to finish everything in other platforms, which sometimes makes me very bored, and it's time-consuming.

V: Good call! How about the least favorite part? And why?

S3: Sometimes I don't know what to do with this new platform. The layout and design are not familiar to me.

V: May I know if you skipped the guidance?

S3: I just clicked "next".

V: Did you pick any purple buttons?

S3: No. I didn't read the headings carefully. I thought I just needed to look at it to get a general idea of the chapter.

V: Ok. Thank you for your feedback. I am writing this down. Because so many students skipped this part, that made me wonder. Then, which part of the Teaching Cell do you think helped you a lot?

S3: It's fun, and short. It has many extracurricular activities. The Teaching Cell allows me to do a short lesson, but it's very useful, because it's personalized. Saved me a lot of time.

V: Great to hear that! That's what Teaching Cell was intended to do! I know there are many technology learning apps and platforms in China. To compare with other teaching technology, what do you think about the Teaching Cell attracts you the most?

S3: I think everything [about the Teaching Cell] is new compared to other apps. Totally personalized with contents, tests, and also steps. And very short lessons. Different students get different experiences. We discussed this after we did the survey.

V: Nice! After I graduate, I will make the Teaching Cell a real product. May I know if you have any suggestions or advice as a potential user?

S3: I wish there will be more subjects, and aligned with our textbooks. And a step-by-step sample lesson tutorial.

V: That's a good suggestion! Thank you very much!