Adaptive Learning Goes to China

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Abstract. Adaptive learning, by definition, adjusts the content and guidance offered to individual learners. Studies have shown that adaptive systems can be effective learning tools. This paper introduces an adaptive learning system, "Yixue," that was developed and deployed in China. It diagnostically assesses students' mastery of fine-grained skills and presents them with instructional content that fits their characteristics and abilities. The Yixue system has been used by over 10,000 students in 17 cities in China for learning 12 subjects in middle school in 2017. The hypothesis is that the Yixue adaptive learning system will improve student learning outcomes compared to other learning systems. This paper describes major features of the Yixue system. A learning analysis of 1,355 students indicates that students learned from using the Yixue system and the results can generalize across students and skills. We also report a study that evaluates the efficacy of the Yixue math program in 8th and 9th grade.

Keywords: Adaptive learning · Mastery-based learning
Diagnostic assessment · Efficacy

1 Introduction

Through machine learning algorithms and data analytics techniques, adaptive learning systems offer learning personalized to students' characteristics and abilities. The intent is to determine what a student really knows and to accurately, logically move the student through a sequential path to prescribed learning outcomes and skill mastery. Many learning products with adaptive features have been developed, such as Cognitive Tutors®, i-Ready®, DreamBox® Learning, Achieve3000®, Knewton®, RealizIt®, ALEKS®. Such systems constantly collect and analyze students' learning and behavior data and update learner profiles. As students spend more time in it, the system knows their ability better and can personalize the course to best fit their talents (Triantallou, Pomportsis, & Demetriadis 2003; van Seters et al. 2012)

Studies have shown that such systems can be effective learning tools (VanLehn 2011) and can promote student engagement. An analysis of learning data from 6,400 courses, 1,600 of which were adaptive, revealed that the adaptive courses were more effective in improving student performance than the 4,800 nonadaptive courses (Bomash & Kish 2015). In general, meta-analyses have found positive impacts from technology-based interventions for mathematics and other subjects (e.g., Cheung & Slavin 2013; Steenbergen-Hu & Cooper 2013, 2014). Recent large-scale studies (Pane

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et al. 2014, 2017) also found positive evidence of intelligent tutors and personalized learning in support of student mathematics performance.

Online education has developed rapidly in China in recent years. According to the China Internet Network Information Center (2017), by December 2016 the number of online education users in China had reached 138 million, accounting for 19% of total Internet users. Yet the development of learning systems, especially systems that adapt to students' needs, is still in the early stages in China, and little empirical evidence exists on their promise in improving learning outcomes.

Yixue Inc. was one of the first organizations to develop an adaptive learning system in China. With the objective of introducing effective learning systems to China, an initial version of the Yixue was created and tested in 2016. Yixue Inc. has developed instructional materials for middle school mathematics, English, physics, Chinese, and chemistry and is working on expanding content coverage to the whole spectrum of K–12 education settings. In 2017, Yixue was used by over 10,000 students in 17 cities in China, representing a broad range of student populations with respect to socioeconomic status, urbanicity, and performance levels.

2 The Yixue Adaptive Learning System

The Yixue intelligent adaptive learning system is a computer-based learning environment that adjust the content and guidance to individual students at both macro- and micro-levels (VanLehn 2006). It provides many opportunities for practice and feedback (Martin, Klein, & Sullivan 2007).

As a **macro-adaptive strategy** supported by psychometric measurement models and artificial intelligence, the system implements competency-based learning and tracks students' mastery of knowledge over time. In competency-based, or *mastery-based*, learning (Park & Lee 2003), students advance to a new learning objective only when they demonstrate proficiency in the current one. In Yixue, students are first given a pre-assessment that diagnoses which knowledge components they have mastered and which ones they have not, according to the predefined hierarchical knowledge structure map. Thus, the system identifies the student's position in the domain model, and the student model is updated accordingly. Then students enter a learning-by-doing stage. The knowledge they demonstrated mastery on during the pre-assessment is skipped during the instructional phase, while knowledge components they were weak on are arranged in an optimal order for learning. As students work, the system simultaneously updates (a) estimates of their competency on each individual knowledge components using a Bayesian statistical model and (b) estimates of overall student proficiency level using an item response theory (IRT) model (van der Linden 2016) and delivers individualized learning content to each student, such as instructional videos, lecture notes, worked examples, embedded practice problems, or unit tests.

The **micro-adaptive strategy** in the Yixue design has to do with provision of just-in-time feedback to students. After a student submits his/her solution to a problem, the system provides immediate feedback on the correctness of the answer. Students may attempt a problem multiple times and request an elaborated explanation of the solution processes step by step if they encounter difficulty. To increase learning efficiency and

prevent students from wasting time in over attempting (such as taking a guess-and-check approach and repeatedly entering incorrect answers), the system stops students from trying after three failed attempts and displays the explanation. For selected subjects where misconceptions are common (e.g., physics), if the system detects a student repeatedly making the same kind of error after a number of practices, it automatically plays an instructional video addressing the misconception associated with the error.

Fundamental to the Yixue design is automatic collection of student performance data and provision of feedback and reports to students and teachers. As students work, the Yixue system automatically collects their responses to questions. Students are constantly presented with summary information on the screen. At the end of each session, the system presents students with a summary report on how they performed with direct links to problem solutions and instructional videos on each topic.

3 Analysis of Data to Determine Learning Effects

We looked at data from Yixue to see if students demonstrated better performance after using the system. In Yixue, each item is tagged with a focal skill. Learning was assessed by comparing students' performance on the first item they were given with their later performance on the second, third, and forth items on the same skill. If students tend to perform better on later opportunities at a skill, this indicates that they may have learned from the instructional assistance the prior items in the group provided. To see whether learning occurred and was generalized across students and skills, we conducted both a student-level analysis and a skill-level analysis. The data came from student use of Yixue mathematics programs in 2017 across multiple grade levels.

For the student-level analysis, we set the criteria to include students who had worked on at least 10 skills and had at least four opportunities on each skill. A total of 1,355 students fit the criteria. We calculated average percentage correct on the four opportunities for all the sets of similar skills that they participated in and then conducted a t test to see if their performance was better at later opportunities. The results showed that the percentage correct increased significantly from students' first opportunity ($p = 0.03$) to the second opportunity and then continued to increase from the second to the third and the forth opportunities ($p < 0.01$).

For the skill-level analysis, we included only skills that had been studied by more than 20 students, with each student completing four problems addressing the skill. There were 662 different sets of skills that met the criteria for this analysis. We conducted *t* tests and saw the average percentage correct per skill increased significantly from each opportunity to the next ($p < 0.01$).

Overall, results from the student-level and item-level analyses suggested that students learned from using Yixue math products, and learning generalized across skills and students.

4 A Quasi-Experiment to Examine Efficacy of Yixue System

In Oct 2017, we conducted a study, aiming at comparing efficacy of Yixue with whole group instruction provided by expert teachers. 78 students from two grade levels (grades 8 and 9) were sampled from local schools and were assigned to treatment condition (38) or control condition (40) based on geographic convenience. Students in the control condition were then split into three groups that received whole group instruction from three experienced teachers from local schools[1]. The study lasted for 4 days, during which each student received about 5 h of instruction each day. The content covered during the instructional sessions included the Pythagorean theorem and its application, rational numbers, expressions, properties of a triangle, and line symmetry. These are representative of content covered in the grade 8 curriculum in local schools. Students in the treatment group were assigned user accounts in the Yixue system and worked on topics above individually during the study with no teacher assistance. In the control group, teachers taught the topics according to learning standards of the province. Students in the control group were not supported by any online learning programs. Math pre- and post-test were administered to both group of students before and after the instructional sessions. Items in the tests were constructed by an experienced math teacher in a local school (not a part of the research team) and reviewed by two independent, experienced subject matter experts. Each test composed of 14 multiple choice, short answer, or constructed responses problems, with a total score of 100 points. Students were given 60 min to complete the test.

First, we looked to see if students learned during the study by comparing their scores from the posttest to the pretest. Across all students, pretest scores were highly correlated with posttest scores ($r = 0.67$). A paired t test showed that students' posttest scores were significantly higher than pretest scores ($p < 0.01$), suggesting that math achievement improved significantly. We confirmed the pretest total score was balanced between the treatment group and control group for grade 8 ($g = 0.13$) and grade 9 ($g = 0.24$). We then used generalized linear modeling to analyze student achievement, with the student posttest scores as the outcome variables, adjusting for pretest score, and treatment condition as a predictor at the student level. The results showed that when student prior achievement was controlled, grade 8 Yixue students ($M = 69.96$, $SD = 22.34$) had significantly higher posttest scores than control students ($M = 61.40$, $SD = 20.99$) ($b = 10.56$, F (1, 32) $= 3.35$, $p = 0.08$, $R^2 = 53.08$, $g = 0.48$).

5 Conclusion

The Yixue adaptive learning system was launched in 2016 and presently has over 100,000 users. In this paper, we introduced features of the system, its implementation model, and theoretical basis. Promising evidence was found that students learned during their use of the system, and a small-scale quasi-experiment demonstrated the efficacy of the system.

[1] No students received instructions from their regular math teachers in school.

The study has limitations; it was quasi experiment with relatively small sample. The study was conducted during a short time (4 days), focused only on selected math topics, and no external measure used. Thus, further research is warranted to examine the efficacy of the Yixue adaptive learning system.

As the technology infrastructure continues to develop in China, there are an increasing number of learning systems developed and there is broad interest in how to select and use such systems. With these studies, we have the opportunity to contribute to much-needed knowledge about adaptive learning in K–12 instruction in China.

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