Application of a Learning Diagnosis System in Chinese Classrooms

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This article introduces the principles and features of a cognitive diagnosis assessment system known as the Chinese Learning Diagnosis System (CLDS). Key issues that have arisen in the development and application of the system are discussed. The CLDS, developed by Biyouxue which is an educational information technology company, provides immediate feedbacks on the effects of learning and teaching based on cognitive diagnosis theory and successfully integrates educational measurement into teaching process.¹

The CLDS

The CLDS aims to establish an “immediate feedback system.” Its implementation consists of five consequent components, as shown in Figure 1.

Item Development

In the initial step, based on the curriculum framework, experts set the goals for learning units at different levels. Guided by Tatsuoka’s (1983, 1995) rule space model, experts then identify the cognitive attributes, as well as the relationships among the attributes for each learning unit. These attributes and their relationships are used to assist item writing and test paper generation in the second phase. This design enables teachers to develop attribute-based items and to identify cognitive attributes for existing test items.

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Figure 1. Implementation process of the CLDS.
Note. CLDS = Chinese Learning Diagnosis System; DINA = Deterministic Input, Noisy, “And” Gate; P-DINA = Polytomous–Deterministic Input, Noisy, “And” Gate; IRT = item response theory; 2-PL IRT = two-parameter logistic item response theory.

Test Paper Generation and Item Bank Building

The CLDS offers an online item management platform, which includes two types of item banks—customized item banks and CLDS cross-school item bank. A customized item bank consists of all the used items at an individual school. This type of item banks provides item cognitive attributes and item parameters which are calibrated using item response theory (IRT) models and cognitive diagnosis models (CDMs). The CLDS cross-school item bank is a shared item bank containing items used by all the participating schools, but only item cognitive attributes are available. In this system, teachers can generate a test paper based on the goal and requirements of a test, by selecting items from the two types of item banks. In addition, they can also add new items into the system if necessary.

Based on the reduced-incidence matrix of items (Tatsuoka, 1983, 1995) and their teaching goals, teachers can determine the structure of a test paper, the type of items, and the number of items for each item type. The system is designed to automatically assess the distribution of cognitive attributes for a test paper specified by teachers and will give a warning if any attribute is

Figure 2. Flowchart for the generation of a customized school item bank.

Note. CLDS = Chinese Learning Diagnosis System. K = the number of schools using the CLDS.

poorly defined. The system also provides scoring rubrics. For multiple-choice items, students either receive a full credit for a correct answer or no credit for an incorrect one. For constructed-response items, rubrics for partial credits are given.

The CLDS cross-school item bank is expected to be improved and expanded in the process of CLDS being used in more schools. See Figure 2 for the flowchart of generating a customized school item bank. After a test, the CLDS can automatically conduct data analysis and have item parameters calibrated for each school. Thus, the customized item bank can be built up gradually for each school. The calibrated information in the CLDS item bank has two parts. The first part includes general information about the test, including grade level, subject, test type (e.g., classroom test, unit test, monthly test, interim test, and final test), learning unit, and cognitive attributes. The second part contains different item parameters, including slipping parameter s and guessing parameter g of a CDM, as well as difficulty and discrimination parameters in the two-parameter logistic (2-PL) IRT model. To ensure psychometric reliability and validity of the item calibration process, the minimum sample sizes for calibrating IRT and CDM model parameters are both set to be 300. If the sample size is below 300 for a given item, only summary statistics based on classical test theory are provided to the teachers. Procedures that automatically weed out low-quality items remain to be developed.

Collection of Test Information

In the CLDS, test answer sheets are automatically generated using a multifunction digital machine and Visual Basic .NET. When teachers input sufficient test paper information, the

CLDS will automatically generate answer sheets. Teachers can download and print these answer sheets before administering the test. Therefore, the system provides an efficient solution by integrating a multifunction digital machine (a printer capable of online data transmission) with cloud computing, ensuring efficient data collection at a low cost. A one-key scanning control program is installed, which allows the multifunction digital machine to scan, photocopy, and print testing materials. When the test is finished, the teacher can use a single keystroke to upload answer sheets to the cloud server of the CLDS. The server identifies, sorts, and processes all image documents. All the multiple-choice items are automatically scored by the cloud server, and all the constructed-response items are manually rated online by teachers.

Data Analysis

The CLDS item bank contains both multiple-choice items and constructed-response items. If items in a test paper are dichotomous, a DINA (Deterministic Input, Noisy, “And” Gate) model with an expectation–maximization (EM) algorithm is used to analyze the probability of a student’s mastery of each cognitive attribute (de la Torre, 2009). If a test paper contains both dichotomous items and polytomous items, analyses are conducted using P-DINA (Polytomous–Deterministic Input, Noisy, “And” Gate) model with an Metropolis-Hastings (jumping M-H) algorithm and Markov chain Monte Carlo–Gibbs sampling (Tu, Cai, Dai, & Ding, 2010).

Feedback and Remedy

The CLDS provides four types of feedback reports for schools, teachers, students, and parents, respectively. In these reports, the cutoff probabilities for determining whether students master the cognitive attributes or not are not provided to avoid judging students’ learning outcome. Rather, to give teachers and students more accurate feedback, the CLDS provides the probability of a student mastering each attribute. Similarly, the average mastering probability for each attribute for every school and class is distributed to schools, teachers, and students, respectively. Sample feedback reports can be found online.²

All the CLDS reports are created online, allowing different stakeholders to find, select, and compare information in an interactive manner. Two types of reports, the student diagnostic feedback report and the class (teacher) diagnostic feedback report, are described below.

The student diagnostic feedback report gives students information about their individual learning, including the mistakes they make in a test, their mastering probability for each attribute, and their strengths and weakness within each content unit. The CLDS also provides recommendations for individualized learning based on a student’s prior test results. For example, student learning can be evaluated by choosing items with the same attribute from the item bank. Students can also specify the test scope and generate a group of individualized items based on their previous mistakes for targeted learning, so as to prevent repetitive, excessive, but aimless practices.

The class (teacher) diagnostic feedback report provides teachers both summative information on original exams for the class and average probability of a student mastering each attribute. This report informs teachers about the attributes that are challenging and easy for students, respectively. As a result, teachers are able to provide more effective and individualized classroom instruction. Finally, the CLDS automatically summarizes types of wrong answers, helping teachers to provide targeted instruction with accommodation. Teachers can also give focused instructions on certain content areas by identifying items with accuracy rates lower than a threshold, for example, 60%.

Table 1. The Distribution of Subjects, Grades, and the Number of Learning Units, Cognitive Attributes, and Items.

Subjects	Grade	No. of learning units	No. of cognitive attributes	No. of items
Mathematics	1-12	138	1,640	40,528
Chinese	1-12	49	426	17,957
English	1-12	18	761	40,436
Physics	8-12	32	475	23,224
Chemistry	9-12	29	644	21,820
Biological	7-12	20	358	29,981
History	7-12	91	2,443	21,820
Geography	7-12	45	775	17,591
Politics	7-12	62	737	23,224
Total	12	484	8,259	236,581

Application and Improvement

The CLDS was put into operation online in September 2012. So far, the system has collected 236,581 items covering nine subjects, 484 learning units, and 8,259 cognitive attributes from primary school to high school (see Table 1). The number of items within each school item bank varies across schools, depending on each school's practices. For example, one item bank that has been used by a school for 5 consecutive years contains 26,903 items covering 156 learning units in nine subject curriculum areas across six grades. In total, as of March 2017, 655 schools, 15,316 teachers, and 388,747 students have used the CLDS, which ends up providing 11,217 tests for schools, generating 22,708 diagnostic feedback reports for schools, 152,943 reports for classrooms, and 6,103,684 reports for individual students.

The CLDS has become one of the main products used for both formative and summative assessments in Chinese classrooms. Given the success of CLDS and positive evaluations from a distinguished panel of education experts, the Chinese Society of Education has suggested to popularize CLDS in Chinese schools. The system has increased the efficiency of teachers' instruction and strengthened students' personalized learning via targeted feedbacks. After using the CLDS, most teachers indicated that the teaching time of one unit in the classroom reduced from 50 min to 25-35 min, allowing teachers to allocate more time to help students who experience difficulties. The implementation of CLDS in Zhengzhou No.5 High School could be considered as a dramatic success. According to annual data from this high school, 3 years after the CLDS had been applied, its enrollment rates to top-tier and second-tier universities have increased by 10.98% and 47.15%, respectively. Meanwhile, students' self-efficacy (Cohen's $d = 0.38$) has also been improved significantly. According to data from the high school, no other intervention has been carried out in this school.

The CLDS, based on measurement theory and CDMs, is a rich data resource for personalized learning and teaching. Nevertheless, there still exist many challenges in enhancing the system and expanding its application to schools over the country. First, the cognitive attributes and the relationships among them need to be modified in response to prior test results and teachers' feedback, which makes attribute-based item writing very difficult. Second, the item calibration could only be implemented within each customized item bank, rather than the CLDS cross-school item bank. Responding to these challenges, the next goal for improving the CLDS is to equate the items across schools, which will facilitate the use of the system in adaptive testing and personal learning. Moreover, the CLDS will be integrated with other online education resources (e.g., digital education platforms) to provide extensive personalized learning resources in the near future.

Authors' Note

Xiaofeng You and Meijuan Li are first set of equal contributors.

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Notes

1. The official website of Chinese Learning Diagnosis System (CLDS) is <http://www.biyouxue.com>
2. See <http://www.biyouxue.com/doclist>

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