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Using Self-Assessment and Remediation to Raise Chinese Middle School Student Achievement in Physics

Yufei Chen and John Leddo

MyEdMaster, LLC

Virginia, USA

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ABSTRACT

Cognitive Structure Analysis (CSA) is an educational framework that helps students identify and address knowledge gaps through self-assessment and targeted remediation. Prior studies have shown its effectiveness across disciplines, including calculus, chemistry, Spanish, reading comprehension, and probability theory. For example, CSA-trained high school chemistry students scored 15 points higher on post-tests than peers who rewatched videos without self-assessment (Ravi & Leddo, 2024). Similarly, CSA in Spanish instruction yielded a 25-point improvement (Nehra & Leddo, 2024), and reading comprehension studies showed experimental groups scoring 93% versus 69% for controls (Prakash & Leddo, 2025a). Middle school applications found that CSA plus remediation improved math scores by 18 points and science post-test scores increased from 77.5% to 98% (Leddo, Clark & Clark, 2025). In history, CSA-trained middle school students scored 91.5% compared to 65.5% for controls. The present student tests whether self-assessment and remediation using CSA can boost achievement in students in China. Thirteen Chinese students were taught a lesson in physics. Seven control condition students were told to reread the material. The other six (experimental condition) students were taught how to self-assess using CSA and performed a self-assessment and then told to reread the material to fill in the knowledge gaps identified by the self-assessment. Both groups were given a posttest on the material taught. Results showed that students self-assessing and remediating with CSA scored, on average, 13 points high on the posttest than did those who simply reread the material. These results indicate CSA plus remediation can benefit students from countries outside the United States.

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INTRODUCTION

Throughout history, assessment has served as a measure of students' learning. Traditionally, "learning" has been defined by the number of correct answers on tests, as per classical test theory, which assumes that a student's total correct responses reflect their knowledge level (de Ayala, 2009).

Assessment methods typically fall into two categories: selecting correct answers from choices or constructing answers independently. Multiple-choice tests, widely used for their efficiency in grading, allow for guessing, which can inflate scores (Chaoui, 2011; Elbrink and Waits, 1970; O'Neil and Brown, 1997). Constructive response tests require students to provide their own answers, encouraging logical reasoning and offering a more accurate measure of knowledge (Herman et al., 1944; Frary, 1985). However, both methods rely on the assumption that correct answers signify learning. This assumption is problematic, as incorrect answers may point to underlying knowledge gaps, while correct answers might result from memorization or guessing, not true understanding.

Cognitive Structure Analysis (CSA) is a query-based assessment method designed to uncover the underlying knowledge concepts a student possesses, identifying the source of errors for targeted remediation (Leddo et al., 2022; Ahmad and Leddo, 2023; Zhou and Leddo, 2023; Dandemraju, Dandemraju, and Leddo, 2024). CSA is rooted in cognitive psychology research, which identifies various knowledge types, such as semantic nets (Quillian, 1966), production rules (Newell and Simon, 1972), scripts (Schank and Abelson, 1977) and mental models (de Kleer and Brown, 1981). Together, these form the INKS framework (Integrated Knowledge Structure), developed by John Leddo (Leddo et al., 1990). This framework suggests that expert knowledge is organized around scripts and principles that enable predictions and explanations.

CSA, which integrates INKS principles, has shown strong correlations with problem-solving performance: 0.966 in Algebra 1 (Leddo et al., 2022), 0.63 in scientific method problem-solving (Ahmad and Leddo, 2023), and 0.80 in precalculus (Zhou and Leddo, 2023). By assessing students' conceptual understanding, CSA enables educators to address knowledge gaps effectively, leading to significant improvements in student performance (Leddo and Ahmad, 2024).

Although CSA has proven effective, the responsibility for diagnosing and remediating students' knowledge gaps lies primarily with teachers, who often manage large numbers of students. Teaching students to self-assess their knowledge could alleviate this burden. Unlike self-explanation, which involves generating explanations for learned material, self-assessment involves evaluating one's knowledge after learning.

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Cynkin and Leddo (2023) demonstrated that high school calculus students could accurately self-assess their knowledge using CSA, while Dandemraju, Dandemraju, and Leddo (2024) extended this finding to chemistry. These studies, however, addressed only the identification of knowledge gaps, not their remediation. Accurate assessment does not equate to addressing deficiencies, just as diagnosing a medical issue does not equate to treating it.

To address this issue, Ravi and Leddo (2024) conducted a study in which high school students learned an advanced topic in chemistry by watching a video. Half the students were told to rewatch the video to fill in any knowledge gaps, while the other half were taught to self-assess their knowledge using CSA and then told to rewatch the video to fill in any assessed knowledge gaps. The group that was taught to self-assess scored 15 points or 1.5 letter grades higher on a post-test than students who simply rewatched the video without self-assessment. Nehra and Leddo (2024) replicated the Ravi and Leddo study to the learning of Spanish. They found that high school students performing self-assessment plus remediation scored, on average, 25 percentage points or 2.5 letter grades higher than those re-reading the material without performing a self-assessment. Prakash and Leddo (2025a) extended the Ravi and Leddo (2024) and Nehra and Leddo (2024) findings to another subject area: reading comprehension. The results revealed a mean post-test score of 8.3 out of 12 (69.17%) for the control group and 11.2 out of 12 (93.33%) for the experimental group. Notably, individual scores further illustrated the disparity: the lowest score in the control group was 41.67%, whereas the lowest in the experimental group was 83.33%. This is the difference between an F letter grade and B letter grade. Following this, another study conducted by Prakash and Leddo (2025b) examined CSA's effectiveness in teaching math, specifically, the topic of Bayes' Theorem, and found a 27-point improvement. Individual scores also highlighted the disparity. The control group's lowest score was 6/20 (30%), whereas the experimental group's lowest score was 15/20 (75%). Following this, a history assessment revealed that students who utilized CSA for self-assessment and remediation significantly outperformed their peers in the control group (Prakash and Leddo, 2025c). Post-test results demonstrated that the experimental group achieved an average score of 87.5%, whereas the control group scored 65.8%, indicating a substantial difference in comprehension and retention of historical concepts.

These results on high school students were further extended by Leddo, Clark and Clark (2025) in their investigation of middle school math. Leddo, Clark and Clark found that middle school students who self-assessed using CSA and then remediated their knowledge gaps scored 18 percentage points higher on a posttest than those who relearned material without first performing a self-assessment.

Following this, Prakash and Leddo (2025d) conducted a study on middle school students' reading comprehension, specifically through an analysis of To Kill a Mockingbird, a novel that

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explores complex themes of ethics and social structure. Students in the experimental group were trained to evaluate their own knowledge gaps and use targeted remediation strategies, while those in the control group engaged with the text without structured self-assessment. Results showed that students in the self-assessment group scored 16 points higher on a posttest than those who re-read the material without self-assessment. Building upon these results, another study examined CSA's impact on middle school students' understanding of science concepts. Students in the experimental group were taught to self-assess their understanding of key science concepts using CSA and then engage in focused review based on their assessed gaps. In contrast, students in the control group reviewed the material without guidance or structured self-assessment. Students using self-assessment scored, on average 20 percentage points or two letter grades higher on a posttest than those who did not (Prakash and Leddo, 2025e). Then, Prakash and Leddo (2025f) extended the CSA methodology to middle school history, focusing specifically on students' understanding of the causes of the American Revolution. Again, those students using self-assessment scored higher on a posttest than those who did not, this time by 29 percentage points.

Following this, Prakash and Leddo (2025g) tested whether self-assessment and remediation would work with elementary school students. This research showed that elementary school students using self-assessment and remediation for math scored an average of 83% on a posttest while those who simply reread the material scored an average of 70%.

All of the above results were conducted with American students and students in K-12. Sathiyamoorthy and Leddo (2025) investigated whether self-CSA plus remediation would boost performance in college students in Scotland. Here, the testbed was college psychology. Students using self-assessment scored 15 percentages points higher than those who simply reread the material. The purpose of the present study is to test the self-assessment and remediation paradigm in another country: China.

METHOD

Participants

The experiment involved 13 participants aged 13–14, all of whom were students in a Grade 8 physics class at a tutoring institution in China. The entire class took part in the study. Participants were randomly assigned to two groups: the treatment group (Group A, n = 6) and the control group (Group B, n = 7). All students participated voluntarily and received no compensation.

Materials

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This experiment focused on the subject of physics. The topic was Refraction of Light. The experiment mainly included four categories: course handout, self-assessment materials, test questions, and scoring rubric.

First, both the treatment and control groups used the same course handout, Refraction of Light, provided by the physics teacher, to ensure the accuracy of knowledge points and the rigor of logical structure. The handout content covered the phenomenon of light refraction, the definition of refraction , the laws of refraction, and practical applications in daily life, such as "objects in water appearing shallower when viewed from the shore" and "stars appearing to twinkle at night."

Second, the self-assessment materials were distributed only to the treatment group and consisted of two parts: a self-assessment example and a self-assessment form. To help students in the treatment group understand what self-assessment is and how to conduct it, we designed a self-assessment template using *Reflection of Light* as the case. This example included facts, strategies, procedures, and rationales, see:

https://docs.google.com/document/d/1CcKfKpwmlcZwfT7QR2mJyJtNG_qmzN3T5ZMll_YkTLo/edit?usp=drive_link

The third material was the closed-book test, which was administered to both the treatment and control groups. The test was co-designed by the physics teacher and the research team to ensure that all items corresponded directly to the handout, with clear wording and moderate difficulty. The test consisted of 11 non-multiple-choice questions with a total score of 100 points, divided into four sections: Basic Knowledge (three fill-in-the-blank questions, 20 points), Understanding of Rules (three short-answer questions, 30 points), Drawing and Operations (three drawing tasks, 30 points), and Applications in Life (two short-answer questions, 20 points). The text paper is available here:

https://docs.google.com/document/d/1xNGW9Ua16Ivqq7b2Uodqd_sG5euaxzwfglnTtyoXxi8/edit?usp=drive_link

Finally, an answer key was developed as the scoring rubric, which ensured that all test papers were graded consistently according to a unified standard.

Procedure

The 14 participants from the Grade 8 physics class were randomly assigned to two groups of equal size: the treatment group (n = 6) and the control group (n = 7). The procedure for the treatment group began with students independently reading and studying the handout on

Refraction of Light. They were then asked to read the self-assessment example, which was designed to help them understand the concept of self-assessment and how to complete a self-assessment form. After reading the example, students completed the self-assessment form, through which they identified knowledge points that were unclear or not fully mastered, as well as areas where they needed further improvement. With these specific gaps in mind, students re-read the handout in order to clarify their questions and strengthen their understanding. Finally, they completed the closed-book test to assess their mastery of the material.

The control group followed a similar procedure, except that they did not engage in self-assessment. Instead, after their initial reading of the *Refraction of Light* handout, they simply re-read the same handout before taking the closed-book test. The total time allocated for the experiment was the same for both groups.

Upon completion of the test, the physics teacher collected the self-assessment forms and test papers from the treatment group, as well as the test papers from the control group. The papers were graded jointly by the teacher and the researcher using the standardized answer key.

RESULTS

The post-test data were analyzed by comparing the treatment and control groups' average scores. Results showed that the treatment group scored an average of 71.2 on the post-test, while the control group scored an average of 47.9. A two-tailed independent samples t-test confirmed that this difference was statistically significant, $t(9)=2.36$, $p=.043$. These findings suggest that students who engaged in CSA-based self-assessment performed substantially better in physics than those who simply reread the material.

DISCUSSION

This study aimed to evaluate the effectiveness of self-assessment techniques in aiding Chinese 8^{th} grade students to identify and address knowledge gaps in physics. The results of this study demonstrate that the application of Cognitive Structure Analysis (CSA) combined with targeted remediation significantly enhances mathematical understanding and overall achievement among elementary school students. The experimental group, which employed self-assessment techniques to identify specific conceptual gaps and address them directly, outperformed the control group by an average of 13 percentage points. These results align with prior research. The present study contributes a new dimension by confirming CSA's effectiveness in teaching students from another country: China.

The implications for instruction are significant. By teaching students to use CSA for self-assessment, educators can help learners identify specific gaps in their understanding of

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percentages, decimals, and proportional reasoning, allowing them to focus on areas that need improvement rather than relying solely on rote practice. Self-assessment using CSA fosters metacognitive awareness of these deeper cognitive skills, encouraging students to move beyond surface-level memorization and engage actively with mathematical concepts, ultimately enhancing problem-solving and analytical reasoning.

Psychologically, the use of self-assessment techniques has been shown to enhance students' self-efficacy and confidence in their academic abilities. This empowerment is crucial in developing independent learners who can navigate complex information and construct well-informed perspectives.

From an equity perspective, structured self-assessment allows all learners regardless of prior background knowledge to tailor their review process to their individual needs. This personalized remediation supports differentiated instruction and can help close achievement gaps, particularly in content-rich subjects like mathematics.

In conclusion, this study reinforces the value of CSA-driven self-assessment in instruction of Chinese students. By enabling students to actively engage with physics content while reflecting on their understanding, self-assessment fosters deeper learning and critical thinking. Embracing this approach can lead to more equitable and effective educational experiences, preparing students to thoughtfully engage with complex ideas and apply analytical skills to real-world contexts.

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