International Journal of Social Science and Economic Research

ISSN: 2455-8834

Volume:11, Issue:03 "March 2026"

Incorporating Student Self-assessment and Remediation into Classroom Instruction Greatly Improves Educational Performance in High School Reading Students

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DOI: 10.46609/IJSSER.2026.v11i03.016 URL: https://doi.org/10.46609/IJSSER.2026.v11i03.016

Received: 4 March 2026 / Accepted: 20 March 2026 / Published: 28 March 2026

ABSTRACT

In previous papers, we have shown that students can be taught to self-assess their own knowledge and knowledge gaps and, by relearning the subject matter with an eye to filling in those knowledge gaps, can improve their performance on tests by an average of 15 to 25 percentage points. These previous studies involved the researchers in the self-assessment interventions, either by managing the instructional process or assisting with the creation of the instructional materials and/or post-tests. In order for an educational intervention to be scalable, it needs to be administered solely by the educators without outside help. Additionally, for the intervention to be attractive to the educational community, it should be free/low cost and minimally disruptive to how teachers conduct their classes. To address this, Gajula and Leddo (2026) report a study involving 4th grade math students learning arithmetic operations over a 3-week period. They found that those using self-assessment scored 18.5 percentage points higher on the unit test than those who did not, while those performing self-assessment increased their performance by an average of 16.5 percentage points over the three-week period, and those who did not showed no improvement. The present study investigates the use of self-assessment and remediation in 11th grade reading in Spain. A teacher taught a unit in adapting to workplace changes, culminating in the class's reading "Who Moved My Cheese?", followed by a post-test on the reading assignment. 12 students engaged in self-assessment and 11 students did not. Self-assessment students, on average, scored 96% on the post-test, while no self-assessment students scored, on average, 82%. Moreover, self-assessment students on average improved 29

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percentage points from their prior scores, while no self-assessment students showed no improvement. Results suggest that self-assessment continues to be a reliable way to improve performance in classroom students and may offer much more benefits than additional instruction alone.

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; Challagulla and Leddo, 2025).

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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.

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

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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 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%. They also showed that using self-assessment and remediation raised elementary students' reading scores by an average of 20.5 percentage points (Prakash and Leddo, 2025h).

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. This study was followed up by one testing whether self-assessment and remediation would raise physics scores of 8th grade students in China (Chen and Leddo, 2025a). In that study, those students using self-assessment and remediation scored 23 percentage points higher than students who did not. Chen and Leddo (2025b) followed up that study with 2nd grade reading students in China and found that those using self-assessment and remediation scored 15 percentage points higher on a post-test than those who did not. Challagulla, Challagulla and

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Leddo (2025) found that elementary school students in India who used the self-assessment method scored 22% higher on a reading post-test than those who did not.

The studies done in the US and other countries all involved a similar format in which the experimenters administered the instructional sessions and/or prepared the instructional materials and post-test to be used. This is appropriate to establish experimental control when exploring a new topic and engaging in systematic replication. However, for the self-assessment and remediation technique to be useful in the classroom, it must also work when incorporated into a classroom's normal mode of operation without the participation of the experimenters. Such an investigation was conducted by Gajula and Leddo (2026). In that study, an elementary school math teacher taught a unit on arithmetic operations. Prior to introducing self-assessment, the teacher gave an interim test. After that, half the students were given the self-assessment templates and told to fill them out, including what they learned after remediating their self-identified knowledge gaps, and half were not given self-assessment templates. Instruction continued for three more weeks, with self-assessment students filling out their templates once a week and the teacher checking to make sure they did. At the end of the three-week period, the teacher gave a final exam. Results showed that students in the self-assessment condition scored, on average, 18.5 percentage points higher on the final exam than did the students in the control condition. Moreover, control condition students showed no improvement, on average, over the three-week period. On the other hand, students in the self-assessment condition improved, on average, by 16.5 percentage points with all but one student raising their scores (the one student who did not show increased performance scored 90% on both the interim and final tests).

The goal of the present study is to conduct an additional investigation in which students use the self-assessment and remediation technique while attending their normal classes and taught the normal lessons by their teachers. This time, we examine the other end of the age spectrum, high school students, and the subject area of reading.

METHOD

Participants

23 male and female students from IES Laurona school in Spain participated in this study. They were all in an 11^{th} grade (US equivalent US) Administrative course. 12 received the self-assessment template and 11 did not. All were taught by the same teacher.

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Materials

The educational content for the students was provided by the teacher, based on her syllabus, including "Who Moved My Cheese?" The post-test the teacher gave was based on "Who Moved My Cheese?"

The Participants in the self-assessment condition were also given a model script, in English, so that they could use it to teach themselves how to self-assess. The script illustrates the process of self-assessment for reading. The text of the script is shown below.

Script for Self-Assessment:

"I want to teach you to assess your own knowledge that you have about something you read. Let's do this by taking an example that you already know. Suppose you wanted to assess your own knowledge about the story The Velveteen Rabbit. If I want to be able to understand stories, I need four types of knowledge. These are facts, strategies, procedures and rationales. Facts are concepts you have that describe objects or elements. For example, in reading, facts can be characters or elements of the setting such as location or time period. Strategies are the general plot sequences of events that authors use to make the points or express the themes or conflicts they write about. Procedures are the specific events in the story that are part of the overall strategy or plot. Finally, I need to know rationales which are the reasons behind the plot elements or events. Rationales could include things like author's purpose, the character's goals (why the characters act the way they do) and how elements of the story reinforce the points the author is trying to make. You can think of facts as telling you "what", strategies and procedures as telling you "how" and rationales as telling you "why".

With this in mind, this is how I might assess my own knowledge of the story The Velveteen Rabbit. For facts, I need to know the characters, setting and time period. The main characters are The Velveteen Rabbit (protagonist), The Boy (protagonist), The Skin Horse (supporting protagonist), the Nursery Toys and Fairy. The Velveteen Rabbit is mainly set in a child's nursery in a house, with minor scenes in the garden and the Fairy's magical place. The story takes place in the early 20th century, around the time it was published (1922).

For the general plot, a little boy receives a Velveteen Rabbit as a toy. Even though he is told by the other toys that he isn't real, he dreams of becoming real through the love of the boy. For specific events, the boy receives the Velveteen Rabbit as a Christmas gift. The Skin Horse tells the Rabbit about becoming real through love. The Rabbit becomes the boy's favorite toy and is loved deeply, but when the boy gets sick, the Rabbit is put aside. The Rabbit fears he may never become real. Later, a magical fairy transforms the Velveteen Rabbit into a real rabbit, fulfilling his wish to live and play freely in the garden.

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For rationales, I believe the author wrote the story to show children that love makes things real and to teach about the value of inner growth rather than appearances. The protagonist is the Velveteen Rabbit because the story focuses on his journey of becoming real. The challenges he faces being a toy, almost forgotten, and not real are necessary to show his emotional growth. The Rabbit has to become real in the end because the story emphasizes the reward of love and loyalty.

When I look over what I wrote, I see that I am good with my facts. I know who the characters are, and I know that the story is set mainly in a nursery and later in a garden. On my story plot and events, I'm not completely sure how the Rabbit was transformed, whether it was only the fairy or the boy's love that caused it. For rationales, I'm not sure why the author chose toys and a nursery as the main setting instead of another location, or why the main challenge had to be about being real rather than something else. I don't think I left anything out."

The post-test given to all Participants to display their knowledge was provided by the teacher. The test was also part of the teacher's original lesson plan.

Procedure

The present study was part of a two-day unit taught by the teacher on dealing with changes in the workplace. Instruction was given by the teacher in both English and Spanish. As part of the instruction, the teacher gave the students "Who Moved My Cheese?" in English. The post-test was based on that reading. Since the self-assessment template was in English, the teacher reviewed the template with those who received it in order to ensure students understood it. Those who received the self-assessment template were instructed to fill it out, and the teacher verified that the students did so. After all instruction and self-assessment (for those in that condition), the teacher gave a 10-question post-test.

RESULTS

In order to fully understand the effects of the self-assessment method on student performance, an initial analysis was done on Participants' prior scores in the course as well as their scores on the test given after the reading lesson. Both prior scores and post-test scores for each group are shown in Table 1.

Table 1: Prior and Post-test Scores Broken Down by Condition

	Prior Score	Post-test score
No self-assessment	76%	82%
Self-assessment	67%	96%

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It appears, at first glance, that the average prior scores for the no self-assessment group were higher than those in the no self-assessment group (76% vs 67%). However, this difference was not statistically significant, ns.

The next analysis that was done was to determine whether students improved their performance between the prior score and the post-test score. For the no self-assessment group, such improvement, if any, would result from the additional instruction provided by the teacher and the additional practice they received from classroom activities. For the self-assessment group, such improvement would result from the additional instruction, classroom practice, and the self-assessment and remediation they did. The data showed that, on average, no self-assessment students' scores increased an average of 6 percentage points between the prior score and the post-test. This increase was not statistically significant, suggesting that no self-assessment students showed no improvement as a result of additional teaching and practice.

For the self-assessment group, the average difference between the formative test and the final test was 29 percentage points. This improvement was statistically significant, $t(11) = 8.00$, $p < .0001$. Not only was there an average improvement in performance in the self-assessment group, each individual student showed an improvement, with improvements ranging from 20 to 60 percentage points (one student actually improved from a 40% prior score, typically considered failing by US standards, to 100%).

The next analysis determined whether the post-test scores of those in the self-assessment group were higher than those in the no self-assessment group. The self-assessment group post-test average was 96%, which was statistically significantly higher than the post-test average of 82% for the no self-assessment group, $t(21) = 2.31$, $p = .03$. Noteworthy is that the lowest post-test score for a student in the self-assessment group was 80%, and that student had a prior score of 40%. There was only one student who scored 80%, with 3 scoring 90% and the rest scoring 100%. Finally, an analysis was done to determine whether the 29-percentage point improvement in prior score to post-test score for the self-assessment group was higher than the 6-percentage point improvement in prior score to post-test score for the no self-assessment group. This difference was also statistically significant, $t(21) = 5.23$, $p < .0001$.

DISCUSSION

This study aimed to evaluate the effectiveness of self-assessment using Cognitive Structure Analysis (CSA) in helping elementary school students in Spain self-assess and remediate knowledge gaps in reading. The findings demonstrate that CSA-trained students significantly outperformed their peers, with the experimental group scoring an average of 14 percentage points higher than the control group and with an average score of 96%. These results align with

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earlier research, such as Prakash and Leddo (2025a), who reported a 93% average post-test score for reading in United States high school students using CSA to self-assess.

The present study is noteworthy in comparison to our previous research in the area of self-assessment and remediation. First, and most importantly, in our previous studies, with the exception of the Gajula and Leddo (2026) study, we the experimenters were involved in the experiment, either by conducting the actual study with the Participants and/or creating the instructional materials and tests that were used in the study. Given that any educational intervention has value only if it can be turned over to educators and have them incorporate that intervention into their daily teaching, preferably with minimal disruption, the present study is a further demonstration that self-assessment can, in fact, be incorporated into a classroom and still produce large educational gains. Moreover, the burden on the teacher is virtually non-existent. What could be easier than handing the students a sheet of paper, asking them to fill it out and then checking to make sure they do?

The second noteworthy finding is that, for the no self-assessment condition students, scores remained statistically equal between prior score and post-test score, indicating that additional teacher instruction did not result in improved student performance on the post-test On the other hand, when adding self-assessment and remediation, students receiving the same instruction as those in the no self-assessment condition showed a statistically-significant 29 percentage point improvement in performance with all students improving a minimum of 20 percentage points.

While it is not clear from the present study whether the improvement in performance in the self-assessment condition students was due to the self-assessment alone or the combination of self-assessment plus additional teacher instruction, it is useful to note that, on average, improvement in the present study did not occur without self-assessment and, in our previous studies, students did show comparable improvement as in the present study without additional teacher instruction and with only self-assessment and remediation. Regardless of whether the teacher's instruction was necessary to produce the educational gains observed in the self-assessment condition students between the formative test and final tests, the self-assessment and remediation activities by the students were necessary to show a higher average performance on the final exam. It is important to note this, since often when new educational interventions are offered to the educational community, there is often pushback based on the claim that teachers are too busy to take on new activities. If the present study's results are illustrative of a widespread phenomenon, the implication is that additional instruction reaches a point of diminishing returns such that a small portion of the teacher's time is better used by introducing the self-assessment technique to students and ensuring that students use it. In terms of return on investment of time spent, this minor investment of time yields far bigger increases in student performance than investing 100% of a teacher's time in teaching alone.

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