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Incorporating Student Self-assessment and Remediation into Classroom Instruction Greatly Improves Educational Performance in Senior Secondary Students in Nigeria

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ABSTRACT

Low student performance continues to plague educational systems around the world. Many practical challenges hinder the push toward improving student performance such as inadequate funding, diverse student populations with different learning needs and styles, large achievement gaps between the highest and lowest performing students, and high student-teacher ratios that prevent teachers from giving students the individual attention they may need. Moreover, some of our recent research in school settings suggests that there may be diminishing returns to increased teaching time (Bajwa, Leddo and Verdu, 2026; Gajula and Leddo, 2026), which may explain why student test scores tend to remain flat over time. In previous papers, we have shown that by empowering students by teaching them to self-assess their knowledge and remediate their knowledge gaps, students can improve their performance on tests by an average of 15 to 25 percentage points. The present study seeks to demonstrate that self-assessment and remediation can compensate for systemic challenges in education by demonstrating that students in an environment with limited educational resources can still greatly improve their academic performance. Accordingly, the present study investigates the use of self-assessment and remediation in a variety of senior secondary school subjects in Nigeria, Africa, a low-income country where many teachers make the equivalent of less than $100 USD per month. Five different teachers, teaching the subjects of chemistry, math, business, government and grammar, taught their normal lessons in their respective subjects. All students were given time to review

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the material. Teachers gave half their students our self-assessment template and had the students self-assess to drive the review process. Then, students received the teachers' standard tests for those units. Comparisons of mean test scores for self-assessment (SA) vs. no-self-assessment (NSA) students revealed the following main effects: chemistry, 82% (SA) vs. 64% (NSA); math, 97% (SA) vs 78% (NSA); business, 86% vs 79%; government, 85% (SA) vs. 52% (NSA); grammar, 91% (SA) vs. 81% (NSA). Results suggest that self-assessment continues to be a reliable way to improve performance in classroom students and may offer much more benefit 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 broad 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

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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).

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 self-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

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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 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.

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

These investigations in classrooms included having the teachers explain self-assessment to the students. While this is a reasonable activity for teachers to perform, we wanted to explore whether reducing teacher workload to the simple requirements of handing the students the self-assessment templates and checking to make sure the students filled them in (without actually analyzing the content) would still produce educational gains. 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 Gajula and Leddo (2026) study was followed up by one involving high school reading (Bajwa, Leddo and Verdu, 2026). In that study, the teacher gave a reading assignment. Afterwards, half the students received the self-assessment for reading and filled it out. Both the self-assessment and no-self-assessment students had an opportunity to review the material before

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a test was given the next day. Those doing the self-assessment scored on average 96% on the test and improved, on average, by 29 percentage points over their previous averages in that class with each student showing score improvement. The lowest test score in the self-assessment group was 80%, which represented 40 percentage points improvement over the student's previous class average of 40%. That student did not have the largest improvement. Another student who also had a 40% average in the class scored 100% on the test given after the reading assignment. On the other hand, those who did not receive the self-assessment template, scored on average 82% on the test and showed no improvement, on average, compared to their previous averages in the class.

The goal of the present study is to conduct an additional classroom investigation, but this time within a country that has a low income and limited resources available for the educational system. Moreover, we want to test multiple subjects to demonstrate the robustness of the self-assessment and remediation method.

METHOD

Participants

Five senior secondary classrooms (equivalent to high school in the United States) from Excel College in southern Nigeria, Africa participated in the study. Each classroom covered a different school subject: chemistry, math, business, government, and grammar. The numbers of students in classes were 32 for chemistry, math and business, 21 for government, and 35 for grammar.

Materials

The educational content for the students was provided by their teachers, based on their normal classroom curriculum. The same was true for the tests given after the lessons. Students in the self-assessment conditions were given self-assessment templates that were constructed to be appropriate both for a high school level and the subject being taught. However, regardless of the subject, all templates showed students how to self-assess the four types of knowledge in the INKS framework: facts, procedures, strategies and rationales. Each template presented students with a description of the self-assessment, an example of what a self-assessment looks like, space for the students to enter their own knowledge and learning needs for facts, procedures, strategies and rationales associated with their respective subjects and space for students to enter what they learned after reviewing the instructional material to remediate their self-assessed knowledge gaps. Sample self-assessment templates can be viewed and downloaded for free at www.myedmaster.com/ways-to-improve-learning/.

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Procedure

Within each class, students were randomly assigned to either the self-assessment or no-self-assessment condition. For chemistry, 15 of 32 students were in the self-assessment condition; for math and business 16 of 32 students in each class were in the self-assessment condition; for government, 10 of 21 students were in the self-assessment condition; for grammar, 17 of 35 students were in the self-assessment condition.

Each teacher taught his or her normal lesson for that class. Afterwards, those in the self-assessment condition were given the self-assessment template and instructions. Both groups were allowed to review the material taught. For the self-assessment students, the teachers examined the self-assessment templates to ensure that students filled them out. The teachers did not grade the self-assessed content or provide students with feedback. The purpose of the inspection was to ensure that any comparison between groups of students would be valid since students who received the self-assessment procedure but did not follow it would be presumed to receive no benefits from the template. After the students completed their review of the material, the teacher gave his or her standard test for that lesson.

RESULTS

Upon completion of the tests, teachers scored each student's test in accordance with their normal grading practices. The scores were anonymously reported to the present research team for analysis. Tables 1 – 5 below show the average, lowest, and highest test scores for each of the subject tests.

Table 1: Average, lowest and highest test scores for chemistry

	Average Score	Lowest score	Highest Score
No-self-assessment	64%	36%	83%
Self-assessment	82%	72%	90%

As can be seen from Table 1, students in the self-assessment condition scored 18 percentage points higher, on average, than those in the no-self-assessment condition. This difference was statistically significant, $t(30) = 3.90$, $p = .0005$. Moreover, the lowest score in the self-assessment condition was double the lowest score in the no-self-assessment condition and actually higher than the average score in no-self-assessment condition. Additionally, the range of scores in the self-assessment condition was 18% (90%-72%), which was much lower that the range of scores of 47% in the no-self-assessment condition. This suggests that one benefit of self-assessment may be to reduce variability across students, making low performing students more like high performance students. To test this hypothesis, the variance of the no-self-assessment group

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scores was compared to the variance of the self-assessment group scores using a Levene's Test. The result showed less variability among self-assessment group scores than no-self-assessment group scores, $F(14,16) = 20.41$, $p < .0001$, one-tailed.

Table 2: Average, lowest and highest test scores for math

	Average Score	Lowest score	Highest Score
No-self-assessment	78%	36%	100%
Self-assessment	97%	76%	100%

As can be seen from Table 2, students in the self-assessment condition scored 19 percentage points higher, on average, than those in the no-self-assessment condition. This difference was statistically significant, $t(30) = 4.07$, $p = .0003$. Moreover, the lowest score in the self-assessment condition was more than double the lowest score in the no-self-assessment condition and nearly equal to the average score in no-self-assessment condition. The individual scores reveal a more impressive picture. Of 16 students in the self-assessment group, one scored 76%, one scored 84%, three scored 96% and the rest scored 100%. By comparison, only one person in the no-self-assessment group scored 100% and only three scored in the 90's. Additionally, the variance of the no-self-assessment group scores was compared to the variance of the self-assessment group scores using a Levene's Test. The result showed less variability among self-assessment group scores than no-self-assessment group scores, $F(15,15) = 8.62$, $p = .003$, one-tailed.

Table 3: Average, lowest and highest test scores for business

	Average Score	Lowest score	Highest Score
No-self-assessment	79%	42%	98%
Self-assessment	87%	78%	94%

As can be seen from Table 3, students in the self-assessment condition scored 8 percentage points higher, on average, than those in the no-self-assessment condition. This difference approached statistical significance, $t(30) = 1.04$, $p = .06$, one-tailed. The fact that the difference between self-assessment and no-self-assessment means was not stronger is not due to low performance by those with the self-assessment template as the self-assessment students scored, on average, comparably to self-assessment students in other classes but to the fact that no-self-assessment students did relatively well without the template. Still, the lowest score for students with the template was roughly equal to the average score without the template. Additionally, the variance of the no-self-assessment group scores was compared to the variance of the self-assessment group scores using a Levene's Test. The result showed less variability among self-

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assessment group scores than no-self-assessment group scores, $F(15,15) = 3.49$, $p = .036$, one-tailed.

Table 4: Average, lowest and highest test scores for government

	Average Score	Lowest score	Highest Score
No-self-assessment	52%	42%	68%
Self-assessment	85%	70%	97%

As can be seen from Table 4, students in the self-assessment condition scored 33 percentage points higher, on average, than those in the no-self-assessment condition. This difference was statistically significant, $t(19) = 10.18$, $p < .0001$. Moreover, the lowest score in the self-assessment condition was actually higher than the highest score in the no-self-assessment condition. In fact, the second lowest score in the self-assessment group was 80. In the no-self-assessment group, only two students scored above 60%, the one who scored 68% and one who scored 62%. These results are perhaps the most impressive because they show that the performance-improving effects of self-assessment do not degrade, even when used with the most difficult subject. Additionally, the variance of the no-self-assessment group scores was compared to the variance of the self-assessment group scores using a Levene's Test. Here, the test showed no significant difference in the variability of test scores between groups.

Table 5: Average, lowest and highest test scores for grammar

	Average Score	Lowest score	Highest Score
No-self-assessment	81%	38%	96%
Self-assessment	91%	74%	100%

As can be seen from Table 5, students in the self-assessment condition scored 10 percentage points higher, on average, than those in the no-self-assessment condition. This difference was statistically significant, $t(33) = 2.60$, $p = .01$. Moreover, the lowest score in the self-assessment condition was nearly double the lowest score in the no-self-assessment condition. In fact, two students in the self-assessment condition scored 78%, and, after that, the next lowest score was 86%. Additionally, the variance of the no-self-assessment group scores was compared to the variance of the self-assessment group scores using a Levene's Test. Even though the range of test scores was 26% for self-assessment group students and 58% for no-self-assessment students, a Levene Test showed no statistically significant difference in the variability of test scores between the groups.

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DISCUSSION

This program aimed to evaluate the effectiveness of self-assessment and remediation using Cognitive Structure Analysis (CSA) in helping high school students in a variety of subjects in Nigeria to improve academic performance. A range of subjects was chosen involving the fields of chemistry(science), math, business (humanities), government (history/civics) and grammar (language). This represents the general gamut of subjects that students take in high school. In all cases, students using the self-assessment and remediation method performed better than those who did not. The average amount of improvement per subject ranged from 7 to 33 percentage points.

There are several noteworthy results from this program. First, the self-assessment technique was remarkably robust. Across the five subjects, the average test performances ranged from 82% to 97%. This held true in even the most challenging subject, government, where the average test score for those not using the self-assessment method was 52%. Here, those using the template scored, on average 85%, which is within the range of the average scores for the other subjects. Moreover, the lowest score for those in the self-assessment group in the government class was 70%, which was higher than the highest score of those without the self-assessment method. When was the last time a 10-minute intervention caused the lowest performing member of a group to outperform the highest member of a group without the intervention?

It is also noteworthy for all the classes, there were students without the self-assessment who scored in the 30s, 40s and 50s percentage-wise on their exams. Such scores are often considered failing. However, the lowest overall score for any student with the self-assessment method was 70, and this was in the most challenging class in which only two no-self-assessment students scored above 60%. The self-assessment method resulted in no students receiving failing scores, with average scores in the 80s and 90s.

Finally, for three of the subjects, chemistry, math and business, the self-assessment method reduced the variability among test scores, closing the gap between low and high performing students. This is significant because, within the educational community, there is often a concern about the performance gap between low and high performing students and whether enough resources are being provided to ensure that low-performing students are receiving the same benefits from education that high performing students are. Often, this debate leads to arguments that more resources need to be provided to support lower performing students to bridge the achievement gap. Such arguments are often challenging as budget-stretched governments are often reluctant to provide those extra resources. The self-assessment and remediation method offers a solution to this challenge. Not only does this method boost every student's performance (see, for example, Bajwa, Leddo and Verdu, 2026), but it disproportionately benefits lower

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performing students, presumably because they have more room for improvement, thus bridging the performance gaps between lower and higher students.

Overall, this self-assessment method has numerous benefits with apparently no downsides. It produces large educational gains across the board, it narrows the achievement gap, it takes only 10 minutes to implement, is completely free, incurs virtually no burden to teacher workload, requires no additional teacher training or change to curriculum/testing, and is politically non-controversial. Furthermore, should a teacher choose, s/he could read the students' self-assessments to see where their learning needs are and use that to inform daily teaching, and administrators could use the aggregated student self-assessment data to make data-driven decisions about curriculum design and selection of instructional materials.

There is one area of further research that would be most interesting. Currently, after self-assessing, students perform their own remediation, which means that they have to review their instructional materials and find the relevant information to fill in their knowledge gaps. Our body of research in self-assessment shows that students can do this very well. However, in recent years, we have seen a proliferation of large language models (LLMs) and their use by students for their schoolwork. While LLMs are very powerful, they are inherently language models that provide answers to the questions they are asked. If 100 people ask the same question, it is still the same question and therefore, these people will get the same answer. However, people do not talk to each other the same way. We do not talk to children the same way we talk to adults. We do not talk to people with little knowledge of a subject area the way we talk to people who know a lot about it. LLMs do not make these distinctions.

Recently, we have been conducting experiments in which we incorporate self-assessment into LLM-based chatbots. Students perform an initial self-assessment on the topic they wish to learn about, and that information is fed to the chatbot with the instructions to tailor answers to students' questions to focus on filling self-assessed knowledge gaps. We have tested this approach on a variety of subject areas (Ganne and Leddo, 2026; Rapolu and Leddo, 2026; Maviti and Leddo, 2025; Maviti, Leddo and Prakash, 2025; Wang and Leddo, 2025). In these tests, students learn a new subject by using either our self-assessment chatbot or a standard LLM like ChatGPT or Gemini. The instruction is followed by a post-test. We find that those using the self-assessment chatbot score, on average, the equivalent of one to four letter grades (roughly 10 to 40 percentage points) higher on the post-test than those who use a standard LLM. One area of future research is to compare educational performance of students who use self-assessment chatbot to remediate their learning needs to that of students who remediate their self-assessed learning needs without technology.

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