

The Role of Language in Anatomy and Physiology Instruction

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ABSTRACT

Research indicates that student learning of science, student attitudes toward science, and their motivation to learn science and pursue science-related careers is related to classroom instruction. This study examined anatomy and physiology (A&P) classes in a south Texas high school where 97 percent of students are Hispanic bilingual learners. Classes were assigned to control or treatment groups, with the treatment group receiving instruction designed to help students develop a deeper understanding of anatomy vocabulary related to brain structures by making connections to these words in everyday life as well as to their understanding of Spanish. Main effects between group and test scores were significant, with the control group reporting higher test scores than the treatment group. We attribute this finding to a bleed-over of the treatment group instructional design to the control group. In addition, significant differences in mean and median scores were observed with respect to intrinsic motivation and self-efficacy. The statistically significant increases in learning for both groups suggests the activity-, problem-, and project-based (APB) curriculum has the potential to be an effective type of instruction, especially for bilingual learners.

Key Words: anatomy and physiology; secondary; English Language Learner; intrinsic motivation; self-efficacy.

○ Introduction

The underrepresentation of females and students of color, Hispanic students included, in science, technology, engineering, and mathematics (STEM) careers has been attributed to lower academic success in science classes and negative attitudes toward science (Kauffmann et al., 2009). Lower academic success is evident by differences in science achievement on standardized tests such as the National Assessment of Educational Progress (NAEP). For example, analysis of the life science component of the 2009 NAEP demonstrates that non-Hispanic students perform higher

than Hispanic students, a finding that is statistically significant (for the analytical tool, see U.S. Dept. of Education, 2013). In addition, Hispanic students designated as limited English proficient (LEP) score significantly lower than non-LEP Hispanic students. A students' science attitude is another significant factor. Interest, self-efficacy, and motivation are all considered important factors in students developing interest in pursuing science careers, including life sciences. For example, whether students received support and experienced success was found to influence their science identity and pursuit of a science-related career (Aschbacher et al., 2010). Not only do Hispanic students often fail to acculturate into science during undergraduate studies, but also career choices of Hispanic women are influenced by self-efficacy (Rivera et al., 2007). Self-efficacy toward, interest in, and motivation to do science are all considered important affective factors in fostering a sustained interest in science and science-related careers.

However, these factors can be influenced by both the type of instruction and the type of resources available in the science classroom. Inequitable distribution of resources in the science classroom such as current textbooks, scientific equipment needed to conduct investigations or experiments, and highly qualified, certified science teachers can effect students' success in school (Barton, 2001; Darling-Hammond, 1999; Oakes, 2000). In addition, schools unofficially track some students into low-level science classes (see, e.g., Yerrick, 1999).

When adolescents become disengaged from learning science, their academic performance is negatively affected, and their interest in STEM careers declines. The result is that these students are often underrepresented in science careers (see, for example (Buxton & Lee, 2010). This claim is supported by studies reporting gender differences regarding high school students' interest in STEM careers (Sadler et al., 2012). Interest at the onset of high school was the greatest

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predictor of the sustained student interest in a STEM career during college years (Sadler, et al. 2012). Tai et al. (2006) also found that the majority of practicing scientists and graduate students in the sciences reported that they developed interest in a science career during high school. The pursuit of science-related careers may be less likely as Hispanic students' high school experience typically does not prepare them for undergraduate STEM courses (Tyson et al., 2007). Such a precollege environment is a leading factor in the pursuit and attainment of STEM degrees at a Hispanic-serving institution (Crisp et al., 2009).

Motivation to Learn Science

How to engage students who are disengaged in learning science is the focus of this study. Social cognitive theory (SCT) posits that learning occurs through observation, which is influenced by the environment, personality traits, and behaviors of the students (Bandura, 1986, 2001, 2006). According to SCT, students with a greater deal of autonomy will have greater motivation to learn. Motivation to learn science has been described as an "internal state that arouses, directs, and sustains science-learning behavior" (Schunk et al., 2008). Highly motivated students are more likely to be more academically successful in math and science classes (Singh et al., 2002). In addition, motivated students are more actively involved in their learning (Schunk et al., 2008).

The science motivation questionnaire or SMQ (Glynn et al., 2009; Glynn & Koballa, 2006) was developed using SCT as a theoretical framework. Later, this questionnaire was modified as the SMQ-II (Glynn et al., 2011). The SMQ-II measures five components: intrinsic motivation, self-efficacy, grade motivation, self-determination, and career motivation. With respect to learning science, intrinsic motivation is described as learning science because one enjoys doing it, without expectation of any external reward. Self-efficacy refers to the extent to which one believes they can do well in science. Self-determination is the degree to which one controls their learning. The last two components, grade motivation and career motivation, refer to the extent to which students are driven to learn science because of an external factor such as a career in science or a grade. This study seeks to better understand how a novel anatomy and physiology curriculum affects not only learning, but also motivation to learn science and whether there is a relationship between learning of science and motivation.

Learning in Anatomy & Physiology: A Gatekeeper Course

Research on learning in anatomy and physiology (A&P) finds that students often resort to rote forms of learning, often delivered exclusively through didactic instruction, which results in only short-term and superficial understanding of the content (Drake et al., 2002). The problem is compounded as students who fail to master vocabulary have even more difficulty learning about complex anatomical and physiological processes than those who have managed to develop basic vocabulary comprehension. This type of didactic, more traditional instruction is not conducive to engaging students who face academic and socio-economic status challenges (Buxton and Lee, 2010). As a result, freshmen A&P courses have a low retention rate and are often referred to as "gatekeeper" courses, meaning they control who will be successful in undergraduate STEM programs, such as in the life sciences and biomedical fields (Harris et al., 2004).

Vocabulary Development

As we discussed earlier, not comprehending the vocabulary can be detrimental to a student's learning of science content. Researchers have identified vocabulary development as a critical factor that can predict reading success (August et al., 2005). Of the effective vocabulary interventions, morphemic analysis has been found to predict success in reading comprehension among 4th and 5th graders (Kieffer & Lesaux, 2008). This approach emphasizes the analysis of relationships between root words and affixes (Young, 2005). Through morphemic analysis, students are able to comprehend the meaning of vocabulary. Helman, Calhoun, and Kern (2015) conducted an intervention study using a combination of morphemic analysis and contextual clues with a small group of 9th and 10th grade students. They found that students' proficiency in science vocabulary increased, and the intervention had a positive influence on their affect.

More specifically, the vocabulary used and how it is introduced in science classes could present challenges to students. Pre-teaching vocabulary through interactive visual aids and meaningful connections to students' prior language experiences can make a difference in how well all students learn science content. This is particularly true for English language learners (ELLs). However, students who can access their Spanish vocabulary knowledge as an asset would be better able to contextualize the content and connect it with applications that they have to the world. Inquiry-based science in bilingual classrooms improves attitudes, learning of science, and language skills for ELLs (Hampton & Rodriguez, 2001).

To develop the language of ELLs, language instruction embedded in content areas, such as anatomy, has been in use in many classrooms across the United States. These strategies focus on teaching content through language, which is a clear shift from the previous ideologies, emphasizing the use of first language for accessing the content (Echevarria & Graves, 2014; Vogt & Echevarria, 2008). These strategies, usually called sheltered instruction, emphasize building both content and language skills simultaneously.

Purpose

The present study examined a nascent A&P curriculum designed to determine whether students recognize bilingualism as a form of linguistic capital as they connect Latin-based anatomy vocabulary to their Spanish language. This pilot study was conducted in a high school A&P class in which the researchers examined whether this type of curriculum helped bilingual and Hispanic students access their home culture and native language to more easily acquire Latin-based A&P vocabulary

The primary goal of the study was to examine the effectiveness of this novel instructional approach. A secondary goal was to investigate whether the approach helped students develop a stronger inclination toward science and science-related careers. Thus, two hypotheses were examined:

1. An A&P, bilingual-focused APB curriculum will have a significant, positive effect on learning.
2. An APB curriculum will have a significant, positive effect on student attitudes (intrinsic motivation, self-efficacy, grade motivation, self-determination, career motivation) toward science and science-related careers.

○ Method

Participants

Participants included 118 students (49 males and 69 females) currently enrolled in an A&P course at a high school in South Texas. Over 93 percent of the participants were 12th graders, about 6 percent were 11th graders, one student was a 10th grader, and no freshmen participated. All students self-reported as Hispanic, Mexican-American, or Latino/a.

Design and Procedures

This study utilized a quantitative approach to data collection and analysis. Before testing, the researchers met with each class to explain the study and obtain informed consent. Over a three-day period, consent forms were collected, and those who agreed to participate were given the Woodcock-Munoz Language Survey–Revised (WMLS), Picture Vocabulary subtest, SMQ-II, and a copy of the demographic survey to take home. The WMLS subtest was administered in isolated rooms to minimize distractions. Throughout the initial period, the principal investigator met with the A&P teacher to train her in the intervention. After the consent was obtained, the pre-test and pre-survey were administered to all students, and the language surveys were completed throughout the remainder of the study.

The intervention was implemented over a two-day period to three “treatment groups” and three “control groups.” The school day consisted of six 45-minute periods; the odd periods were designated the experimental groups, and the even periods were designated the control groups. Control groups (periods 2,4,6) received a traditional sheep brain dissection lesson in which they were provided a dissection guide and were responsible for identifying different structures. Treatment groups (periods 1,3,5) received the same lesson in addition to an activity in which they developed a deeper understanding of root words by making connections to these words in their everyday life, as well as understanding of Spanish. Thus, both groups dissected a sheep’s brain using a traditional dissection guide. The treatment group participated in an additional activity in which they completed a graphic organizer that required them to create sentences with the names of the parts of the brain as the group activity. Part of the group activity involved using words in Spanish that were similar to the parts of the brain being studied. For example, many students were able to relate *dura* to tough and *mater* to mother, and with guidance understood that the Latin-based term *dura* was related to the Spanish word *duro*, which may have made it easier to recall that *dura mater* means tough mother. During the dissection, a guided-inquiry questioning approach was used to help students make the connection to the structure *dura mater* and why it is called *dura mater*—it is a protective (*mater*), tough (*dura*) covering of the brain. The lesson continued in a similar manner for a second day. The following day, the post-test was administered. The environment was conducive to testing, and most students completed the post-test in less than 30 minutes.

Measures

Demographic Survey. A demographic survey was used to collect typical background information such as parental income and education. Yearly household income options ranged from < \$10,000 (coded as 1) to > \$100,000 (11), in \$10,000 increments. Highest parental education level attained was coded in seven categories:

grade school (coded as 1); high school/GED; vocational/technical school; associate’s degree; bachelor’s degree; masters or professional degree; and doctorate degree (7). The mean income for residents in this county and students participating in this study is approximately \$35,000. In addition, 33 percent report a family income of less than \$10,000.

Language proficiency and dominance. Spanish and English language proficiency were measured using age-adjusted Picture Vocabulary subtest scores from the WMLS (Woodcock et al., 2005). To determine participant’s language dominance (i.e., if they were more proficient in English, Spanish, or had similar proficiency in each), difference scores were computed for each participant. This was done by subtracting the English from the Spanish language score. The sample was then divided into three groups based on the overall difference scores established a priori: Spanish-Dominant (> 10), Balanced Bilinguals (–10 to +10), and English-Dominant (> –10). Approximately 89 percent of the students were English-dominant bilinguals, 11 percent of the students were balanced bilinguals, and none of the students were identified as Spanish-dominant bilingual. The mean Picture Vocabulary scores in English ($M = 87.8$, $SD = 8.8$) and Spanish ($M = 55.0$, $SD = 18.1$) were below the age-corrected norm of 100 ($SD = 15$). In addition, approximately 90 percent of the students in this study fell below the age-corrected norm.

Science Attitude. The “Is Science Me?” (SMQ-II) survey instrument (Aschbacher et al., 2010) was administered to students before and after the intervention to examine how the intervention affected their engagement, attitude, and interest in science and science careers. This 25-item survey offers a reliability coefficient range of 0.83–0.92 for each scale (intrinsic motivation, self-determination, self-efficacy, career motivation, and grade motivation). Moderate to high construct validity has been established for each scale, with a validity coefficient range of 0.47–0.90 (Glynn et al., 2011).

Content Knowledge Assessment. The pre- and post-assessments consisted of a one-page, 20-item, black-and-white worksheet divided into three parts. The first section consisted of a drawing of the brain with 10 areas the students were to identify by using items from a word bank. The second part consisted of five to six multiple-choice items. The third part consisted of five terms—coronal, corpus callosum, *arbor vitae*, *dura mater*, and mammillary bodies—and asked to define each part of the brain and use it in a sentence. The content codes were *no answer*, *incorrect*, *partially correct*, and *correct*. Responses that included an understanding of the meaning of the word were coded for etymological connection. All of the pre-test responses were either *no answer* or *incorrect*.

To lessen the researcher’s assumptions and inclination to distort the codes designated to each question, two researchers individually coded the data for accuracy of content and etymological connection. An interrater reliability analysis using the Kappa statistic was performed to determine consistency among raters. Two researchers in this project investigated the feedback from the participants by using a coding blueprint until they were in agreement at least 90 percent of the time, indicating a high interrater reliability, which also reinforces the validity of the results. Both researchers independently coded each of the open-ended responses and discussed any response on which they disagreed. Disagreements were discarded from the reported findings.

○ Results

To test hypothesis 1, that the novel instructional approach would be effective, pre- and post-test content knowledge scores were compared. Scores were analyzed using a 2(group) x 2(test score) repeated measures ANOVA with pre- and post-test scores as the repeated measure. Main effects between pre- and post-test scores were observed: $F(1,62) = 37.665, p < .05, \eta^2 = .378$. Main effects between group (treatment vs. control) and test scores were significant— $F(1,62) = 6.280, p < .05, \eta^2 = .092$ —with the control group reporting higher post-test scores than the treatment group. The researchers attribute this finding to unexpected issues that arose during implementation of the pilot lessons; these are addressed in the discussion. Interaction effects were not observed. Additionally, statistically significant gender differences were not observed. These findings are summarized in Table 1.

Table 2 reports the coded responses for open-ended content knowledge questions, which included, as before, *no answer*, *incorrect*, *partially correct*, and *correct*. Frequency of responses on pre-test, open-ended questions was 0 percent. Students provided a partially correct or correct response 8.5 percent of the time on the post-test, and provided an accurate understanding of the meaning and origin of the term 17.4 percent of the time on the post-test. Students were able to using the terms correctly and make the connection to the meaning of the term 15.1 percent of the time. Responses that included an understanding of the meaning of the word were coded for etymological connection. All of the pre-test responses were either *no answer* or *incorrect*. The interrater reliability for the raters was found to be $Kappa = 0.82$.

To test hypotheses 2, that the novel instructional approach would enhance students' attitudes about science, the relations between pre- and post-test science motivation were examined using the SMQ-II.

The SMQ-II is divided into five components (intrinsic motivation, self-efficacy, grade motivation, self-determination, career motivation). Each component consisted of five items. An example of an intrinsic motivation item was "I enjoy learning science." An example of a self-efficacy item was "I am sure I can understand science." An example of a grade motivation item was "It is important that I get an A in science." An example of a self-determination item was "I study hard to learn science." An example of a career motivation item was "My career will involve science." Students responded using a five-point Likert scale: Never (0), Rarely (1), Sometimes (2), Often (3), Always (4). Pre- and post-survey mean scores were compared using a paired *t*-test. Statistically significant differences between mean pre- and post-SMQ-II scores were observed with respect to four of the five components, grade motivation being the exception. These findings are reported in Figure 1.

Next, the median pre-survey responses were divided into three groups: low motivation or bottom 25 percent, high motivation or top 25 percent, and mid-motivation or middle 50 percent. These findings are reported in Figure 2. Although grade motivation, self-determination, and career motivation did not change significantly for any group, significant differences in median scores were observed with respect to intrinsic motivation and self-efficacy. A Wilcoxon sign test indicated that students in the low motivation group increased in two components, intrinsic motivation (IM; $Z = 2.738, p < .05$) and self-efficacy (SE; $Z = 2.287, p < .05$), whereas students in the high motivation group showed a statistically significant decrease in both IM ($Z = 2.419, p < .05$) and SE ($Z = 2.39, p < .05$). In addition, students in the mid motivation group showed a statistically significant decrease in SE ($Z = 2.719, p < .05$).

Lastly, correlations between science motivation and learning gains were examined. Mean post-intrinsic motivation scores and post-test scores were positively correlated: $r(68) = .28, p = .02$.

Table 1. One-way analysis of variance (ANOVA).

	Group	Mean	df	F	p
Pre- vs. post-test score difference?	Pre- Post-	33.5% 49.8%	3	37.665	<.001
Treatment vs. control post-test difference?	Treatment Control	46.3% 53.4%	3	6.280	<.05
Gender difference?	Male Female	47.1% 50.5%	3	—	n.s.

Table 2. Examples of coded student responses for open-ended content knowledge questions.

Response	Examples of coded responses (term; code)
<i>Partially correct or Correct</i>	<ul style="list-style-type: none"> Connects both hemispheres (corpus callosum; partially correct) Plane that divides the body into front and back sections (coronal; correct)
<i>Etymological connection</i>	<ul style="list-style-type: none"> Tree of life (<i>Arbor vitae</i>; etymological connection) Tough mother (<i>dura mater</i>; etymological connection) Crown area of head (coronal; etymological connection)
<i>Partially correct or Correct, Etymology</i>	<ul style="list-style-type: none"> The hard white covering protecting the brain. The <i>dura mater</i> is very tough. (<i>dura mater</i>; correct, etymological connection) A white substance in the cerebellum, known as the tree of life (<i>Arbor vitae</i>; correct, etymological connection)

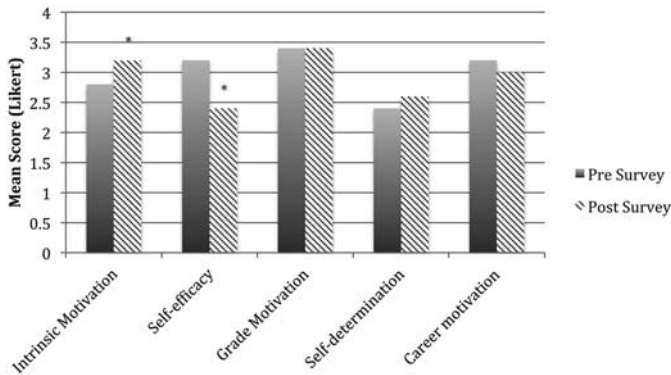


Figure 1. Mean pre- and post-survey scores for the five components of the Science Motivation Questionnaire II (SMQ-II). Each component consisted of five items, which were averaged for a component score using a five-point (0–4) Likert scale. Asterisk (*) <math>p < 0.05</math>.

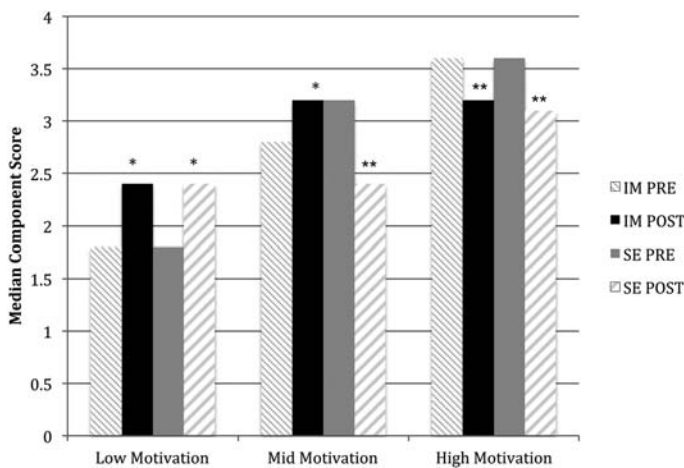


Figure 2. Median scores by intrinsic motivation (IM) and self-efficacy (SE). IM Pre = median intrinsic motivation pre-survey score; IM Post = median intrinsic motivation post-survey score; SE Pre = median self-efficacy pre-survey score, SE Post = median self-efficacy post-survey score. Asterisk (*) = significant increase from pre-survey scores ($p < 0.05$); ** = significant decrease from pre-survey score ($p < 0.05$).

Mean post-self-efficacy scores and post-test scores were also positively correlated: $r(67) = .32, p < .05$.

○ Discussion

Statistically significant increases in learning are reported for both treatment and control groups, suggesting the APB curriculum has the potential to be an effective type of instruction that can transform learning in anatomy classes, especially for bilingual learners. We report that the control group made statistically significant gains over the treatment group. Two explanations, supported by researchers' observational notes, are: (1) the teacher was implementing treatment strategies in both treatment and control classrooms, and (2) the school schedule affected the amount of time the teacher was able

to implement the treatment curriculum in day 1 first period, which was a treatment group. The actual instructional time used for the period was approximately 20 minutes of the 45-minute period. This reflects the idea that research in a classroom setting can be challenging in that it is not possible to create a completely controlled environment (Filmore & Filmore, 2012).

Regardless, this study was a two-day pilot of a curriculum that helps students connect their everyday life and Spanish language to Latin-based root words. We report statistically significant learning gains as measured on pre- and post-tests for both groups. In addition, students demonstrated an understanding of brain structures and were able to make a deeper connection to the meaning of the vocabulary of brain structures. Although the frequency of these qualitative responses are low, this likely results from the problems that arose from implementing a pilot study in a short period of time.

Participants in this study were all Hispanic students in a rural school district from families with incomes at or below national, state, and county means. Given the short duration of this study, the significant increases in science motivation components are encouraging. Although the increased motivation scores are statistically significant, the magnitude of the increases question whether the gains are of practical significance. Although small gains would be expected with a short intervention, it will be interesting to examine changes in science motivation at the end of the school year and completion of this study.

Following continued intervention, we plan to implement three additional lessons with the same group of students before the school year ends, as well as in additional classes. However, disaggregation of the pre-survey scores into low motivation, mid-motivation, and high motivation also might explain the small gains in intrinsic motivation and the no change with respect to self-efficacy. Students with low motivation in two components (intrinsic motivation and self-efficacy) before the intervention reported significant increases, whereas students with high motivation on the pre-survey reported significant decreases. In addition, mid-motivation students reported a significant decrease on the self-efficacy component of the SMQ-II. Students reporting higher motivation scores before the lessons were also higher-achieving students, as evidenced by the positive correlation between post-test scores and mean scores on the intrinsic motivation and self-efficacy components of the SMQ-II. These students are often more comfortable with traditional and/or didactic instruction, and feel challenged when presented with a different type of instruction. According to the teacher, this was the first dissection the students had performed during the academic school year. We predict that these initially highly motivated students will rebound and will report higher gains when the survey is administered at the end of the year, as they become acclimated to a new type of instruction. Lastly, the positive correlation between student learning and intrinsic motivation, as well as between student learning and self-efficacy, supports findings that students with higher motivation will have greater academic achievement (Singh et al., 2002).

Implications

Our findings echo the belief that schools teach students to be skilled in understanding text, rather than experiencing the power of text (Selvester & Summers, 2014). Schools seldom teach adolescents "how their personal and collective power is related to influence and access to resources, or that the degree of ease to which their

rights are exercised in America is related to socioeconomics, race, language, and gender” (Selvester & Summers, 2014, p. 19). With language barriers embedded in the textbook, it is much harder for ELL students to be skilled in text and less likely to be turned on by subjects such as anatomy. U.S. statistics reveal that Hispanics are underrepresented in careers that rely on the life sciences as a foundation. Science teachers can draw on the wealth of cultural and linguistic knowledge that is often overlooked among these underrepresented groups. By including engaging vocabulary and instructional approaches that value cultural strengths, not only do they increasingly meet student-learning outcomes and improve interest in science subjects, but also they open the door for career paths that have previously been closed by students’ struggles in a gateway course.

Limitations

The findings of this pilot study are cautiously optimistic as we report learning gains and improved motivation toward science in an anatomy and physiology class of high school students in which they access their knowledge of Spanish as a means of learning anatomy vocabulary. However, this pilot study had two methodological limitations. First, the teacher’s implementation of the curriculum was inconsistent with the procedure in the research design, as the team has reported. Ideally, the teacher would have had professional development on vocabulary development strategies and the implementation of a research study. Teachers generally lack knowledge and interest in research (Luttrell et al., 2010). Second, this study included only one teacher and a small number of students. The teacher’s professional development in using these teaching strategies might have minimized the teacher effect.

Future directions

Building on the current study, we will include a professional development component to ensure that the curriculum is implemented to its full benefit. We will increase the number of students by reaching out to additional school districts to repeat the experiment. This will also allow us to sequentially introduce multiple teachers to the experimental condition after establishing the baseline performance of their students. By doing so, more anatomy teachers will have teaching strategies that they can use and that will yield benefit to the students’ learning and motivation while increasing the fidelity of the intervention methodologies. Specifically, conducting the study in additional districts will allow us to observe not only the main effects of the intervention but also the effects of a more diverse Hispanic population (income, language fluency) and teacher experience.

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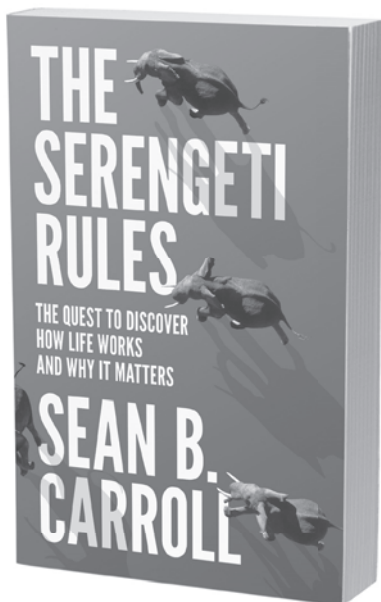
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