2019

Project ACCESS: High School Student Learning of Academic Vocabulary in the Rio Grande Valley

Angela M. Chapman
The University of Texas Rio Grande Valley, angela.chapman@utrgv.edu

Project ACCESS: High School Student Learning of Academic Vocabulary in the Rio Grande Valley

Angela M. Chapman
University of Texas Rio Grande Valley

Research
Supported by:

GREATER TEXAS
FOUNDATION

Abstract

Academic language can be a major obstacle to students' learning in science and math. For English Language Learners this challenge can be even greater. One reason this challenge prevails is the persistent deficit perspective toward students whose native language is Spanish. One way to address this issue is to leverage students' knowledge of Spanish and personal culture to develop a deeper understanding of academic vocabulary in high school math and science courses. Project ACCESS (Acquisition of Curricular Content for Exceptional Success in STEM) seeks to challenge the assumptions and biases toward students in the Rio Grande Valley (RGV) who have been marginalized in their STEM classes and are underrepresented in STEM. Specifically, Project ACCESS is (1) creating a consortium to examine P-16 STEM education practices in the RGV and (2) developing, implementing, and testing the use of multiple vocabulary strategies (MVS) in high school math and science classrooms. Results from Phase 1 indicate that MVS are highly effective in high school algebra, anatomy, and biology but have limited effectiveness in chemistry and physics. In addition, efforts to address STEM education issues in the RGV are well underway. Research findings, progress toward STEM education consortium efforts, and next steps are discussed.

The National Assessment of Educational Progress (NAEP) highlights science achievement disparities in the U.S. (NCES, 2016). The disparities are evident when the data is disaggregated based on socioeconomic status (SES), ethnicity, and English Language Learner (ELL) status, as summarized in Table 1. The data raise important questions about how we are educating K-12 students in science and ensuring they are prepared for postsecondary education. Similar trends are observed by State of Texas Assessments of Academic Readiness (STAAR) Biology performance measures. For example, in fall 2018, 54% of high school students did not meet the state standards (Texas Education Agency, 2018). When disaggregated based on English Language Learner (ELL) status, special education status, or students identified at-risk the disparity widens. For example, 64% of ELLs, 74% of students with special needs, and 59% of at-risk students did not meet state standards on the fall 2018 STAAR biology exam and will require academic intervention. Similarly, 58% of students with special needs and 32% of ELL students did not meet state standards on the fall 2018 STAAR Algebra I exam (Texas Education Agency, 2018b).

Table 1. Mean scores on the 2015 12th grade Science NAEP.

Variable	Mean Life Science Score	Mean Physical Science Score
All Students (public & private)	151	150
Students designated low SES	135*	134*
Students designated as ELL	100*	111*
Students reporting as Hispanic	136*	136*
Students reporting as White	161*	160*

Scale: 0-300. *Significantly different from all students mean score with $p<0.05$.

There have been tremendous focused efforts on how to broaden participation of underrepresented groups in science, technology, engineering, and mathematics (STEM) careers. For example, the literature attributes low retention in undergraduate freshman courses such as general chemistry, Algebra I, or general biology to inadequate academic preparation during high school (Harris, et al, 2004), which is often related to teachers' pedagogical content knowledge or PCK (Van Driel, Verloop, & de Vos, 1998). There is extensive research on best practices in math and science teaching, including inquiry-based instruction (for example, see NCES, 2011). Regardless, students often resort to rote forms of learning (Drake, Lowrie, and Prewitt, 2002; Notebaert, 2016).

One of the challenges that makes it difficult for K-12 students to achieve literacy in math and science classes is the vocabulary load in science and math textbooks (Groves, 2016). Groves found that secondary science textbooks contain anywhere from three to eight Tier 3 (academic) vocabulary words per page. Many students struggle with learning academic vocabulary, which is considered foundational to literacy (Snow, 2010). Even though students need a strong academic vocabulary foundation in order to be successful in their science and math courses, the vocabulary used and how it is introduced in science classes presents challenges to students. This is particularly true for students who are English Language Learners.

Research has shown that allowing students to use their native language in the classroom can help learn the English language (Krashen, 2000). In addition, allowing ELLs to access their native language can help with vocabulary acquisition (Valdés, 2001). Lee (2003), has called for quitable practices in science classes that recognize students' linguistic and cultural capital as a resource to help students bridge home language with scientific language. While ELLs have fluency in Spanish, they do not recognize their knowledge of the Spanish language as an asset in learning science. This institutionalized implicit bias toward speaking Spanish in many schools has been documented as bilingual students are often told to speak English by teachers and administrators in their classes (Stevenson, 2015). Thus even though Previous ELLs better learn science when they utilize both languages (Lee, 2005); bias against the use of Spanish in classrooms discourages students from speaking their first language (L1) in the classroom, affects participation in science classes and academic achievement(Stevenson, 2015). This is supported by earlier work in that multiple instructional strategies, including those that help students connect Spanish to science vocabulary, improve learning and attitudes toward science (Chapman, et al. 2017).

The objectives of this project are two-pronged. The first objective is to address the successes and challenges in P-16 STEM education for the Rio Grande Valley through the development of a STEM Education Consortium. This group is made up of stakeholders from P-12 RGV school districts (administrators, teachers, and students) and UTRGV faculty from varied disciplines, including science education, bilingual education, special education, early child and elementary education, biology, chemistry, physics, and engineering. Second, the research objective is to develop and test science and math curricula embedded with multiple vocabulary strategies on high school students. The research question guiding this study is, What is the effect of MVS on students' learning of content in high school Algebra II, Biology, Anatomy, Physics, and Chemistry?

Methods

Study Participants and Design

High school Algebra II, Biology, Anatomy, Physics, and Chemistry teachers and their students were recruited from public schools in the Rio Grande Valley. In year 1, two Algebra, three Biology, two Anatomy, two Physics, and two Chemistry teachers participated in this study. For year 2, new teachers were recruited from a neighboring district including three Biology, one Algebra, and one teacher assigned to both Chemistry and Physics. 98% of students in this study have been identified or self-identify as Hispanic (*n*=680).

Working professional development sessions were made up of discipline-specific faculty, preservice secondary teachers, a science education faculty member, and high school teachers. The sessions took place at the beginning and end of the academic year, in which all members met for two days. During these sessions, each discipline-specific group (for example, a Biology faculty, an undergraduate Biology teacher candidate, and the high school teachers) developed units of instruction and identified key vocabulary, and multiple vocabulary strategies were developed. Tested lessons and key vocabulary are shown in Table 1.

The intervention involved the teaching of the lesson that was developed during the professional development session. High school classes were randomly assigned to either a treatment group (MVS + regular instruction) or control group (regular instruction). Control groups received regular instruction, while treatment groups received multiple vocabulary strategies in addition to regular instruction. Regular instruction varied based on the discipline as the anatomy, biology, and chemistry lessons were inquiry- and lecture-based while the physics and algebra lessons were predominantly lecture-based using PowerPoint. Regardless, all treatment groups received MVS in addition to the regular instruction. The vocabulary and content covered for each class are shown in Table 1. These strategies are described in Appendix A and include morpheme analysis (MA), etymology/word origins (E), meaning association (A), visuals (V), first language translation (L1), first language association (L1A) and personal/cultural relevance (R).The vocabulary and strategies were reinforced in treatment groups throughout the remainder of the lesson, with a minimum target of 10 repetitions (Hu, 2013).

Table 1.

Overview of lessons and vocabulary by discipline

Subject	Lesson Topic	Vocabulary (strategies used)
Biology	Mendelian genetics	Alleles (E, MA, L1) Genotype (E, MA) Phenotype (E, MA) Dominant (E, MA, L1A) Recessive (E, MA, L1A) Zygote (E, MA, L1A) Heterozygous (E, MA) Homozygous (E, MA) Monohybrid cross (MA, L1a, R) Dihybrid cross (MA, L1A, R)
Chemistry	Chemical Reactions	Coefficient (MA, R, E, L1) Subscript (MA) Synthesis Reaction (MA, L1) Exothermic (MA, R) Endothermic (MA, R) Combustion Reaction (MA) Decomposition Reaction (MA) Replacement Reaction (MA, R) Equivalent (MA, R) Dehydration Synthesis (MA, R)
Anatomy	Cardiovascular System	Atrium (E, L1) Ventricle (E, MA, L1A) Interventricular (MA) Atrioventricular (MA) Valve (MA, L1) Bicuspid/Tricuspid (MA, A, L1, L1A) Mitral (L1, A) Pulmonary (L1) Aorta (E) Endo/peri/myocardium (MA, A, L1A) Coronary (L1, L1A) Septum (E, L1, L1A) Vena cava (L1, E)
Algebra II	Quadratic Functions	Quadratic (E, L1, A) Vertex (E, MA) Interval (MA, A) Coefficient (MA, A) Polynomial (E, MA, L1, L1A) Exponent (MA, E, L1, L1A) Graph (E, L1)
Physics	Sound Waves	Medium (A, R) Mechanical wave (R, L1, A) Transverse wave (E, MA) Longitudinal wave (MA, R) Crest (E) Trough (E) Period (E) Amplitude (E) Constructive interference (E, MA, L1) Destructive interference (E, MA, L1) Node (E, L1, L1A)
E-etymology, MA-morpheme analysis, A-meaning assoc., R-personal relevance, L1/L1A– 1st language/assoc.		

The PI or an undergraduate research assistant taught the lessons in all treatment classes. This approach allowed students to learn while the classroom teacher observed how the MVS were taught. The teacher completed an observation protocol (Appendix B), which was used to document the type and frequency of vocabulary strategies used. Students in both the control and treatment groups completed an assessment before and after the intervention.

Data Collection and Analysis

Quantitative data were collected from pre/post assessments and classroom observations. All students were given written assessments at the beginning and end of the units. The assessment will also include a vocabulary strategy questionnaire to measure changes in how students are answering questions. An observation instrument was created to demonstrate fidelity of implementation between control and treatment groups, and to facilitate classroom teacher learning of MVS. The teacher observed the teaching of high school students and recorded every time a different vocabulary acquisition strategy (morpheme, visuals, L1, L1 association, meaning association, etc.) was used. The teacher was taught how to use the instrument, used the instrument while the principal investigator (PI) was teaching, and then debriefed after the lessons were taught. Quantitative data from pre- and post-assessments were first analyzed by comparing gain scores between control and treatment groups using independent samples t-tests, and then confirmed using a 2 (group) x 2 (test score) repeated measures analysis of variance (ANOVA) with pre- and post-test scores as the repeated measure (Creswell, 2013). In addition, the frequencies of MVS from the observation instruments were used to demonstrate fidelity of implementation.

Findings

Objective 1: Student learning and attitudes toward science and math

Students in the treatment group were provided with multiple vocabulary strategies during the lesson. For example, during the Algebra II lesson on quadratic functions, students learned the meaning of the word *quadratic* using etymology, L1, and L1 association. A student version of the worksheet (appendix B) was provided and students were first asked to translate "*Recinto cuadrado en el que tienen lugar los encuentros de boxeo"* to English. The questions were all directed to help students understand the meaning of the term *quadratic equation*, an equation in which the highest exponent is squared. This term was chosen in part because it may be a false cognate (Lubliner & Hiebert, 2011), as students often confuse the term *quadratic* (squared) with the term *quadrangle* or *quad*, meaning "four." This can lead to a choosing a common distractor on standardized tests in which students choose an answer that has an exponent to the 4^{th} power because they associate quadratic with four.

Based on the observation protocols, the most common MVS utilized in control groups were visuals (i.e., diagram) and morpheme analysis. The treatment groups showed higher use of all MVS for all subjects. This is important as it helps to establish fidelity of implementation in the research project.

Table 2 shows a comparison of gain scores (, i.e., the percentage-point difference between post- and pre-test scores, between the treatment and control groups for each subject area. For example, Algebra II students showed significant learning gains in both control and treatment groups, but the gain scores of the treatment group were 18.9 percentage points higher than those of the control group (24.6 points versus 5.7). Thus, the regular instruction is effective, but the inclusion of MVS improves learning even more. Significantly higher gain scores were found for treatment groups in all five disciplines.

Table 2
Mean gain scores by subject and group

		Gain Scores (Post – Pre)	
Course	*n*	Comparison (%)	Treatment (%)
Algebra II	93	5.7	24.6***
Anatomy	162	32.9	38.9*
Biology	148	18.0	26.0**
Chemistry	193	30.3	34.4*
Physics	84	23.7	28.2*

Significantly higher *** - $p<0.001$, **- $p<0.01$, *-$p<0.05$

One goal of the research was to understand if students' attitude toward math and science was effected by the use of MVS during instruction. Previous research has shown that students with lower pre-test scores not only show greater learning gains when they receive instruction incorporating MVS into a high school nervous system lesson, but also significantly higher self-efficacy and instrinsic motivation toward science than students with higher pre-test scores (Chapman, et al., 2017). To explore this question, the Science (or math) Motivation Questionnaire II (SMQ-II; Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011) was administered prior to the lessons. The SMQ-II measures five components: intrinsic motivation, grade motivation, career motivation, self-determination, and self-efficacy. In this study, a ceiling effect was observed in that students reported high mean scores. In other words, a significant effect on students' motivation was not observed because students' scores on the SMQ-II prior to receiving the treatment were already quite high. While students express a positive attitude toward science and math, this does not necessarily correlate with high academic achievement nor do they recognize that Spanish is a linguistic asset that can help them learn in science and math. To address this, the SMQ has been modified to include language questions. Next steps are discussed later.

Objective 2: STEM Education Consortium

The interdisciplinary steering committee is made up of faculty and students representing the colleges of education, engineering, and sciences as well as informal STEM educators. In its second year, the conference was attended by 247 participants, an increase from 141 in the previous year. The theme for the second year was “Challenging Our Assumptions: Towards Transformative Practices in STEM Education.” A fundamental goal of this conference is ensuring that all STEM educators are prepared to successfully implement best practices in STEM education, from preschool to college, for all students-- and to do so with a heightened awareness of existing systemic inequities, hegemonic ideologies, and how educators impact student engagement, interest, and academic achievement. Conference participants are the doers, with a willingness to be introspective and have difficult conversations about what works as well as what doesn’t work and how to transform that knowledge into success for STEM learners. The conference included participants from all disciplines of P-16 STEM education, from high school students to STEM faculty (Table 3).

Table 3

Attendees at 2nd Annual RGV STEM Education Conference

Attendee Discipline	Percentage
Doctoral Student	1.9
High School Student	13.1
Undergraduate Preservice Teacher	30.0
Elementary Educator	10.0
Secondary Educator	7.5
Higher Ed – Administrator	1.9
Higher Ed - Education	13.8
Higher Ed – STEM	13.8
K-12 Administrator	1.9
Other, including informal STEM Education	6.3

Presenters included STEM and STEM Education faculty from across the United States and Mexico, local P-12 STEM educators, and high school students from La Joya ISD. Presentations were diverse, including hands-on and inquiry-based practitioner sessions; critical discussions with high school students, P-16 STEM educators and administrators, and informal STEM educators; and overviews of current STEM education research. Keynote and plenary speakers discussed the importance of mindfulness in education, well-being and health of educators, and the social, cultural, and emotional aspects of STEM education at all ages. Attendee feedback demonstrated the success of individual sessions as well as the conference as a whole. The predominant themes that emerged from attendee feedback included networking with STEM education faculty from around the country; diversity of attendees (including the inclusion of high school students) and presentations; appreciation for specific workshops and presentations (especially implicit bias in STEM classrooms, Apples and Gravity, and roundtable discussions that included high school students, P-16 educators and administrators); and interest in topics covered by the keynote and plenary speakers (especially discussions of mindfulness and wellness in education and social, cultural, emotional aspects of learning in STEM). Below are some responses from attendees when asked what was the most valuable or strongest aspect of the conference:

- For me, I can't get out of my mind this session in which the high school students talked about their lives and their experiences with education. It really was eye-opening to myself who is born in the US to northern European immigrants and many people who have been here for centuries.
- I found the diversity of sessions to be refreshing. I thought the content of the sessions was meaningful. I left the conference energized and renewed with ideas.
- The speech made by Dr. Tobin was very interesting to me. His emphasis on calming the body and mind is something I have been thinking about for a few years now. I have practiced Yoga for more than two years now and it has changed my life, I am living proof of what Dr. Tobin talked about and the importance of meditation. I have thought of coming up with a way we can integrate Yoga and meditation into the public school curriculum.

- I valued the opportunity to build new contacts; I get to meet with Dr. Gallard and Dr. Tobin in person and with the Director of RGV Code during the preconference session.
- I got to see how peers from other HSIs are implementing STEM education related activities to enhance student success.
- How to make STEM type of lessons, we got to try out two simple ones that I could adapt to my subject. I also got a book to use for further projects/lessons.
- The variety of topics covered. The presence and participation of high school students, teachers in practice, and educators. The ease of access to all sessions.
- It brought out great conversations and sparked challenging questions. It also provided the perspective of the student through the La Joya ISD students which is rare in a conference.
- The conference brought together all kinds of people with different past and current history of involvement with STEM education. It was humbling to sit together in the same room and wrangle with the shared problems together. Of course, I love the social constructivist framework of the keynote speakers and researchers. It is an outstanding characteristic of the conference.
- Bringing as a whole from early childhood to graduate students and professors from all areas of education to discuss science educational concepts.
- I enjoyed the diversity of the participants. From high schoolers to university educators, every participant showed a fresh new perspective.
- The interesting subject matter and the use of personal stories to illustrate concepts. I also loved the collaborative approach to the sessions and the interactive conversations.
- Bringing students and student teachers on board and letting them lead panel inclusiveness in everyway possible.

One presenter and attendee, Melinda Wright, sent an email after the conference to share her perspective on the conference:

> I just wanted to let you know how much I enjoyed the conference! I have been teaching for over 30 years and this was one of the best conferences I have been to in years! From the preconference social to the closing speaker, I was just so impressed. The venue was outstanding…and the sessions meaningful! I took lots of notes from my sessions, and I am excited to implement these ideas and share them. As a presenter I was especially impressed with having three high school students in my audience. I really appreciated their active participation in my session. We know that teachers can sit in the back with their arms folded in a "you’re not going to teach me anything new" attitude, but these students were right up front and so enthusiastic, it was a breath of fresh air!

Suggestions for the third annual conference are to continue the inclusive approach and expand on early childhood and elementary STEM learning, especially development of critical thinking and problem solving skills. The steering committee will continue to expand this conference as a national and international conference, with the goal of UTRGV emerging as a leader for transformative STEM education practices for diverse student populations.

Discussion

The research on effectiveness of MVS and the efforts toward transformative practices in STEM education are the two main objectives of Project ACCESS. In each of the following sections, a potentially transformative practice is described.

Potentially transformative practice 1: Academic vocabulary acquisition in math and science

The results of this study demonstrate that MVS are a way to improve learning for high school students in math and science classes. The greatest treatment effect was observed in Algebra II, most likely because the algebra teachers in this study rely primarily on visuals and problem-solving and make minimal use of MVS during regular instruction. In contrast, the biology, chemistry, and physics teachers commonly use morpheme analysis and try to help students connect their native language of Spanish to learning in the classroom even during regular instruction. Anatomy lessons utilized a combination of morpheme analysis, L1, and etymology. Although these strategies were not used in the unit for this study, it is possible that students' prior experience helped them to understand and learn the content. Thus, the treatment effects were smaller in classrooms where linguistically responsive practices are already being used. Changes to the research study have already begun with (1) a modification of the science and math motivation questionnaire to include statements that measure if students use native language to learn content, and (2) modification of the interview protocol to include pre- and post-interview questions that address use of native language and other strategies in their prior courses and in the study as well as assessment questions that will better help the researchers understand students conceptual understanding of content and academic language. The SMQ-II has been modified to add Spanish language statements, for example, “I believe my knowledge of Spanish will help me learn in math or science.” Currently, the modified survey is being administered in order to determine validity and reliability.

Regardless, by providing students with a variety of vocabulary strategies as part of classroom instruction, student learning was improved. The treatment of multiple vocabulary strategies helped to leverage the students’ linguistic assets, including students whose native language is Spanish. When students in the treatment group were provided explicit strategies that included helping them utilize their first language or make first language associations, they made significantly greater learning gains than students who were not given the same strategies. This is critical if bilingual students and/or ELLs are to develop a deep and meaningful understanding of academic vocabulary.

These findings support previous work (Chapman, et al, 2017; Chapman et al, forthcoming) and provide evidence that using strategies which access high school students’ cultural capital, including language, and which students find personally relevant, improves learning of academic vocabulary and content similar to the Lee et al. (2005) study on the science literacy achievement of culturally and linguistically diverse elementary students in urban schools.

Suriel (2014) reported that students should be encouraged to identify cognates during instruction that underscores conceptual understanding. Using MVS allows students to develop a deeper understanding of academic vocabulary and connect it to the math and science concepts. In addition to the impact on learning, studies have reported that many ELLs do not recognize their knowledge of Spanish as an asset in classrooms or hesitate to speak Spanish in class because of the bias and deficit perspective (Stevenson, 2015). In this study, students were provided with the opportunity to make explicit connections between Spanish and science. This is a first step toward shifting from deficit thinking toward linguistic capital as a form of cultural capital in the science classrooms. Part of this success comes from considering the cultural and linguistic capital of bilingual students, and helping them connect their Spanish language to science vocabulary. We need to continue to push the frontiers in bilingual science education from deficit to asset views of our students and value what they bring to the classroom. Even though most of the students in this area are either bilingual or ELLs, there is a common view that English is the "right" language and that Spanish is not.

Currently, a STEM MVS database is being developed and is composed of more than 300 key academic terms, along with several strategies for teaching them. It is expected that this database will more than double by the end of year 3.

Potentially transformative practice 2: Multi-tiered educative curriculum development

The project was designed for discipline-specific STEM faculty, science education faculty, high school STEM teachers, and undergraduate preservice STEM teachers to work collaboratively to identify challenges and develop the MVS for specific lessons that can be tested. During the professional development sessions, everyone becomes knowledgable with respect to the vocabulary, curriculum, and how to teach. In addition, this model also has educative curricular potential. Educative curriculum materials have been offered as one way of simultaneously supporting teacher and student learning (Davis & Krajcik, 2005). This type of curriculum uses a self-discovery approach to help teachers develop a deeper understanding of the content and how to teach it. The model presented here can become a professional development model for inservice teachers as either the science education faculty and/or undergraduate preservice teachers model the lessons in the high school classroom while the teacher observes using the observation protocol (Appendix A). During the next phase, we will continue to interview preservice and inservice teachers to better understand how this helps them to develop as a pedagogical content expert and culturally responsive teacher.

Potentially transformative practice 3: Shifting the culture of STEM education

The second Annual STEM Education Conference has laid a transformative foundation by creating a purposeful, inclusive environment that brings everyone involved in P-16 STEM education together. The conference created a space for educators and students to have open, honest, and critical discussions about what is happening in the classroom.

For example, discipline-specific roundtable discussions were intentionally designed to include faculty from the representative discipline as well as bilingual education, special education, early childhood, STEM education, P-12 educators, and high school students. Each roundtable was led by a moderator who facilitated a P-16 vertical alignment of a topic or concept specific to the discipline (i.e., Newton’s Laws in the physics discussion). This novel discussion allowed everyone to understand what children are learning in STEM from preschool to college, and challenging the assumptions that are often made about our students. One high school student asked, “Why is there so much pressure for us to memorize in our classes?” The discussion that followed allowed the teachers, faculty, administrators, and students to share their perspective, leading to a vertical alignment that helped participants highlight strengths and better understand challenges in the STEM curriculum. These sessions were recorded and will be transcribed allowing for an in-depth qualitative analysis.

Another transformative aspect of this conference was the building of local scholarship, including high school students. One of the presenters, a young assistant professor, stated, “Ken Tobin taught me the importance of developing the local before the national or international. It is local scholarship that leads to the development of undergraduate and graduate students who eventually become good colleagues and great thinkers, and can impact the communities in which they live and work. Yes, there is a time and place for both national and international work but that should never overshadow nor replace the local. In my view of the world, this conference has underscored this belief. A great example is an invitation you extended to high school students and some of their teachers. Not only were their teachers exposed to new ways of thinking, but the students were also. Perhaps this is the first time they had experiences that go beyond rote memorization and the development of good test-taking skills, making their experience much more critical as they had an opportunity to think on their own." Often educators assume they know what is best and don't always listen to students. Part of the vision is to ensure that students have a seat at the table and a voice that is heard. The goal is to continue growing local scholarship such that the RGV is informing the national and international audiences on transformative practices that lead to success for Hispanic students in STEM education. The goal is to continue pushing the frontiers of STEM education toward transformation of practice, research, and policy by challenging assumptions about what students know and can do in STEM through critical dialogue and reflection.

References

Beck, I., McKeown, M. G., & Kucan, L. (2002). *Bringing words to life: Robust vocabulary development*. New York: Guilford.

Buxton, C. A. & Lee, O., (2010). *Diversity and Equity in Science Education: Research, Policy, and Practice*. Multicultural Education Series. Teachers College Press.

Buxton, C., & Lee, O. (2010). *Diversity and Equity in Science Education* (J. A. Banks Ed. 1st ed.): Teachers College Press.

Chapman, A., Ward, H.C., Tiwari, A., Weimer, A., Duran, J., Guerra, F., Sale, P. (2017) The Role of Language in Anatomy and Physiology Instruction. *The American Biology Teacher*, 79(3), 184-190.

Chapman, A. Srinivas, R. Sale, P. (forthcoming) Efficacy of Multiple Vocabulary Strategies in High School Anatomy for Bilingual Learners. For consideration in *School Science and Mathematics*.

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches*. Thousand Oaks, CA: Sage.

Davis, E.A., & Krajcik, J.S, (2005) Designing educative curriculum materials to promote teacher learning. *Educational Researcher*, 34(3), 3 -14.

DeLuca, E. (2010). Unlocking academic vocabulary. *The Science Teacher*, 77(3), 27.

Drake, R., Lowrie Jr, D., & Prewitt, C. (2002). Survey of gross anatomy, microscopic anatomy, neuroscience, and embryology courses in medical school curricula in the United States. *Anat Rec (New Anat), 269*, 118-122.

Glynn, S. M., Brickman, P., Armstrong, N., & Taasoobshirazi, G. (2011). Science Motivation Questionnaire II: Validation with science majors and nonscience majors. *Journal of Research in Science Teaching*, 48, 1159-1176.

Groves, F. H. (2016). A longitudinal study of middle and secondary level science textbook vocabulary loads. *School Science and Mathematics*, *116*(6), 320-325.

Harris, D. E., Hannum, L., & Gupta, S. (2004). Contributing factors to student success in anatomy & physiology: lower outside workload & better preparation. *The American Biology Teacher*, *66*(3), 168-175.

Helman, A. L., Calhoon, M. B., & Kern, L. (2015). Improving science vocabulary of high school English language learners with reading disabilities. *Learning Disability Quarterly*, 38(1), 40-52.

Hu, H. C. M. (2013). The effects of word frequency and contextual types on vocabulary acquisition from extensive reading: A case study. *Journal of Language Teaching and Research*, *4*(3), 487-496.

Lee, O. (2003). Equity for linguistically and culturally diverse students in science education: A research agenda. *Teachers College Record*, *105*, 465–489.

Lee, O. (2005). Science education and student diversity: Synthesis and research agenda. *Journal of Education for Students Placed at Risk*, 10(4), 431-440.

Lee, O., Deaktor, R. A., Hart, J. E., Cuevas, P., & Enders, C. (2005). An instructional intervention's impact on the science and literacy achievement of culturally and linguistically diverse elementary students. *Journal of Research in Science Teaching*, 42(8), 857-887.

Lee, O., Quinn, H., & Valdés, G. (2013). Science and language for English language learners in relation to Next Generation Science Standards and with implications for Common Core State Standards for English language arts and mathematics. *Educational Researcher,* 0013189X13480524.

Lubliner, S., & Hiebert, E. H. (2011). An analysis of English–Spanish cognates as a source of general academic language. *Bilingual Research Journal*, *34*(1), 76-93.

National Center for Education Statistics (2016) Institute of Education Sciences, U.S. Department of Education, Washington, D.C.

Notebaert, A. (2016). Student Perspectives on General Learning Compared to Learning Anatomy. *The FASEB Journal*, *30*(1 Supplement), 369-3.Texas Education Agency (2018). *State of Texas Assessments of Academic Readiness: Summary Report Biology.* Retrieved from: Biology Statewide_FinalTX_STAAREOC_Fall18_Summary_Reports_v2_ADA-3

Snow, C. (2010). Academic language and the challenge of reading for learning about science. *Science*, 328(5977), 450-452.

Suriel, R. L. (2014). The triangulation of the science, English, and Spanish languages and cultures in the classroom: Challenges for science teachers of English language learners. In *Multicultural Science Education* (pp. 209-229). Springer Netherlands.

Stevenson, A. D. (2015). "Why in This Bilingual Classroom… Hablamos Más Español?" Language Choice by Bilingual Science Students. *Journal of Latinos and Education*, *14*(1), 25-39.

Texas Education Agency (2018b). *State of Texas Assessments of Academic Readiness: Summary Report Algebra 1.* Retrieved from: Algebra I Statewide_FinalTX_STAAREOC_Fall18_Summary_Reports_v2_ADA-2.pdf

Tyson, W., Lee, R., Borman, K. M., & Hanson, M. A. (2007). Science, technology, engineering, and mathematics (STEM) pathways: High school science and math coursework and postsecondary degree attainment. *Journal of Education for Students Placed at Risk*, 12(3), 243-270.

Van Driel, J. H., Verloop, N., & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching*, 35(6), 673-695.

Wellington, J., & Osborne, J. (2001). Language and literacy in science education. McGraw-Hill Education (UK).

Young, E. (2005). The Language of science, the language of students: Bridging the Gap with Engaged Learning Vocabulary Strategies. *Science Activities*, 42(2), 12-17.

Appendix A: Observation Protocol

Teacher name:
Data & Day:
School:
Period:

Strategy	Frequency	Comments
Morpheme analysis Breaks down word into prefix, suffix, root		
Visuals—uses any visual such as a graphic organizer, diagram, color coding, etc.		
Mnemonics- memory i.e.- PEMDAS for order of operations		
1st language (Spanish)- introduces/taught the word in Spanish		
1st language association- making connections to Spanish		
Meaning association- finding substitutes making connections		
Relevance- making everyday life connections		

Appendix B: Graphic organizer for "quadratic function"

Word: Quadratic Function

Please translate the following: *Recinto cuadrado en el que tienen lugar los encuentros de boxeo.*

Square enclosure in which the boxing match takes place.

What is this a photo of?

Spanish: Cuadrilátero
English: boxing ring

What is the English term for cuadrilátero?
Quadilateral

What are the characteristics of a cuadrilátero in this photo?

- Four sides of the same length
- Four corners

A cuadrilátero/quadrilateral has how many sides? Quatro/four

To determine the area of the cuadrilátero above, you would multiple what? Length x width in this case L=W, so L^2 or **x^2**.

Be careful! A quadrilateral is a shape with four sides whose interior angles add up to 360^0. A **cuadrilátero** or boxing ring forms the shape of a **square** whose four sides are equal in length and interior angles are the same.

Quadratic is from Latin quadrus, meaning a square and is related to quattor meaning four. It can be easy to confuse the two! The term quadratic equations came about in the 1660s to describe equations containing the square of x.

A quadratic equation is one where the highest exponent is squared (x^2).
A quadratic function is one that involves the square of x.

Which of the following is/are an example of a quadratic function? Explain your reasoning.

A. $y = 2x - 3$
B. $y = 2x^2 + x + 1$
C. $y = 4x^4 + 2x^2 + x + 1$

A is incorrect because its highest exponent is to the 1st power. C is incorrect because its highest exponent is to the 4th power (be careful!). **B is correct because its highest exponent is squared (to the 2nd power).**