Supporting Academic Growth of English Language Learners: Integrating Reading into STEM Curriculum

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Abstract

English Language Learners (ELLs) in the U.S. have recently received growing attention in educational research because of their struggle in academic performance, especially after the launch of the Common Core State Standards (CCSS) and assessments in 2009. Unfortunately, ELL students are required to take these standardized tests in English language regardless of their proficiency level in reading. Despite increased focus and resources of implementing STEM (Science, Technology, Engineering, and Math) curriculum in K-12 education, there is a strong evidence that ELL students do not attain commensurate performance when compared to their native English-speaking peers. The integration of Art into STEM disciplines has evolved STEM into STEAM. Lately, there has been much discussion in the educational field that the acronym STEAM should be further evolved into STREAM by integrating Reading. The purpose of this study is to investigate the efficacy of integrating STEM and Reading curriculum in K-12 education to reduce the achievement gap between ELL and non-ELL students. Practical classroom strategies for classroom teaching and instruction are discussed.

Keywords: English language learners, STEM reading integration, STREAM, content-based language learning

1. Introduction

According to a 2009 survey by the U.S. Department of Education (USDOE National Center for Education Statistics, 2009), about a quarter of students in the United States are immigrants or the children of immigrants. In 2013, the National Center for Education Statistics estimated that 10% of K-12 students in the U.S. can be classified as ELLs and predicted that the number will continue to increase to constitute 40% of the student population by 2030 (USDOE National Center for Education Statistics, 2015). A considerable percentage of these children, especially those with Spanish-speaking backgrounds, are falling behind in school. For instance, more than five million schoolchildren with Spanish-speaking backgrounds exhibit lower academic achievement in all subjects because they are still learning English (Maxwell, 2012). Student diversity across U.S. school districts is in the rise due to increasing numbers of ELLs (USDOE National Center for Education Statistics, 2015; Maxwell, 2012). In fact, ELLs represent a very diverse group in terms of knowledge to their native language, educational skills, access and affordability to early childhood programs, and immigration status. These students, unfortunately, have common negative trends in grade retention and educational outcomes, particularly in the area of reading (National Assessment of Educational Progress "NAEP", 2015; Turkan et al., 2014). Poor academic performance and grade retention are highly associated with higher school dropout rate (Hernandez, 2012). Research show that three policy reforms - increased attendance in school, enhanced instruction in English, and use of early intervention methods - could improve school achievement for ELLs, boost their economic well-being as adults, and increase their economic and social contributions to the American society (Short, 2017; Sparks, 2016).

There is an overwhelming evidence that ELL students are extremely challenged with the implementation of CCSS and consistently underperforming their English-speaking peers in all subjects, including STEM disciplines (Abedi & Gándara, 2006; CCSS Initiative, 2017a; NAEP, 2015; Sullivan 2011). These findings promote the need of more research in this area and the support required for ELL students in STEM education. Research exploring the relationship between STEM subjects and reading skills is scant. However, researchers agree that the low scores of ELL students in math and science can be attributed to their limited ability in reading and comprehending the English

language (Maxwell, 2012; Polat et al., 2016; Wright, 2006). Furthermore, STEM subjects normally include complex linguistical text and technical words that can impede the learning of ELL students (Huerta & Spies, 2016). The inadequate reading capabilities of these students in STEM subjects will hinder their ability to generate inferences, interrupt their aptitude for robust information processing, and delay their cognitive development to achieve successful conceptual understanding about the domain.

Over the last decade, STEM employment grew at a much faster pace than non-STEM jobs; 24% versus 4% (Howard & Ifenthaler, 2018; Langdon et al., 2011). Moreover, STEM employment is predicted to continue to grow much faster than other occupations for the foreseen future. Individuals in STEM fields enjoy 29% higher wages and 50% higher rate in obtaining a college degree compared to their counterparts in non-STEM fields (Howard & Ifenthaler, 2018; Langdon et al., 2011). Taylor (2014) estimated that during the next three decades 90% of the U.S. labor force growth will come from new immigrants and their children and predicted that ELL students will constitute a significant portion of the work force. Hence, STEM education becomes a critical component in preparing ELL students with the skill level needed to make them prosper in a job market that is fueled by advancements in science and technology.

2. Purpose – What Do We Want to Achieve by Integrating STREAM into ELLs' Education?

School districts across the U.S. are seeing a rapid increase in enrollment of ELLs. According to the U.S. Department of Education (USDOE) and the National Institute of Child Health and Human Development (NICHD), 25% of children above the age of five speak a language other than English at home and it is estimated that by the year 2030 about 45% of school students will speak English as a second language (USDOE & NICHD, 2010). Many of the nation's school districts have experienced a demographic shift where half of the nation's teachers had at least one ELL in their classrooms (USDOE National Center for Education Statistics, 2015; USDOE & NICHD, 2010). Compared to their monolingual peers, ELLs tend to perform lower in academic achievement and have negative outcomes in all educational subjects, particularly in STEM education. General education teachers sometimes are indecisive to refer ELLs to special education because they cannot determine if the issues of ELLs' difficulties with learning core STEM subjects are related to the acquisition of second language or a learning disability (Brown, 2007; Fuhui et al., 2014; Short, 2017). Many of these teachers are also confused regarding the appropriate time for referrals since school districts policies are not clear whether ELLs must acquire a minimal level of English proficiency before the referral process can start (Hakuta, 2013; Weinburgh, 2014).

Furthermore, teachers are faced with considerable challenges when dealing with the education of ELLs at a time when school districts are experiencing a serious increase in the population of these students. Politics, logistical shortcomings, identification procedures, infrastructures for data collection, and institutional capabilities are complicating the way we deal with the already complex needs of ELLs. Therefore, it is imperative that we make systematic efforts to take advantage of and, at the same time, critique the emergent empirical knowledge base on ELLs who are struggling to learn to read. Integrating STREAM into ELLs education can become a vehicle for adequately developing and engaging ELL students in STEM subjects. Adding reading to STEM curricula can provide the vital spark that is needed to assure a successful learning and advancement of ELL students in the fields of science, technology, engineering, and math. The integration of reading in the STEM subjects for ELLs must be done in an interdisciplinary and applied approach to ensure deeper learning across disciplines, improve comprehension and knowledge in content area, and motivate students to further develop their academic language skills.

3. Strategies – Curriculum Models Integrating Reading into STEM Education and Their Benefits to ELLs

In the last few decades, several researchers have asserted that reading skills of academic language are key factors to the success of ELL students in the math and science education (Abedi, 2002; Kieffer, 2008; Minicucci, 1996; Short, 2017; Tong et al., 2014). Many school districts in the United States have implemented scripted literacy programs that use a great deal of fluency and phonics in early education to accommodate ELLs in their classrooms (Ajayi, 2005; Herrera, 2010; Lesaux et al., 2014). However, the research is still meager at best when it comes to integrating reading into STEM subjects as a mean to improve ELL students' achievement in such subjects. This gap in research necessitates developing effective strategies to address the chronic achievement disparities between ELLs and their native English-speaking peers in STEM subjects.

When studying ELLs, the children's educational environment, cultural background, and language experiences should be considered. Teachers should learn more about children's language experiences at the time of school entry, since

findings from studies related to ELLs in non-school settings may not apply to outcomes associated with changes in the language environment after school entry. Therefore, the prediction of children's outcomes may differ depending on whether they were exposed to two languages from birth or they were exposed to their parents' native language at home and English at the time of school entry. Moreover, the emphasis on instruction strategies and observing progress would likely impact student outcomes, more specifically ELLs who historically did not perform well on measures of student achievement.

The author of this study conducted a systematic review analysis by examining the volume and current state of empirical research in education literature that addressed integrating reading into the math and science education of ELL students in U.S. public schools. The author limited the results to only peer-reviewed articles during the last three decades, between 1988 and 2018. Two web-based search engines were used: GALILEO, an online library search system, and Google Scholar search engine. Table 1 summarizes the author's findings.

Table 1. Strategies Recommended by Researchers to Integrate Reading into Math and Science Subjects

Strategy	Definition	Benefits	Challenges	Best Practices	Assessment and Effectiveness	Relevant Publications
Sheltered Instruction Observation Protocol (SIOP)	• Arguably, one of the best models for working with ELLs • Teaching content subjects while promoting English language development • Consists of 8 components along with 30 features	• Cooperative learning • Use of visuals and demonstrations • Targeted vocabulary development • Language-intensive instruction	• Professional development to enhance content-area teachers • Logistic constraints may limit the availability of time and resources to support SIOP	• Six-step process developed by Marzano and Pickering (2005) • Three Tier Model developed by Beck et. al (2002) • Explicit Instruction Approaches developed by Zwiers (2008)	• Professional development to teachers of ELLs • Measuring teacher effectiveness • Students gains in content areas and English	• Guarino et al. (2001) • Settlage et al. (2005) • Hansen-Thomas (2008) • Batt (2010) • Center for Applied Linguistics (2011) • Szpara (2017)

Cognitive Academic Language Learning Approach (CALLA)	• A research-based program that integrates content area instruction and language development with explicit learning strategies for ELL students	• Enhances academic achievement of ELL students • Reduces cognitive load to make academic content more accessible for ELLs • Develops reading comprehension skills • Develop thinking skills	• Understanding students' prior knowledge to develop their higher order thinking skills • Failure of teacher preparation programs in preparing teachers on implementation of instructional models designed for teaching ELLs • Stakeholders buy-in to develop curriculum and materials based on CALLA	• Use of scaffolding to help ELL students learn academic content via a second language • Implementing metacognitive strategies by using metalinguistic awareness and context embedded communication • Students can set learning goals and assess their successes	• The CALLA Handbook provides a checklist and a teacher log for teachers to monitor their implementation of CALLA, Chamot & O'Mally (1994) • Students assess their own learning by comparing their prior knowledge with the new information	•Chamot (1995) •Chamot & O'Malley (1996) •Szpara & Ahmad (2007)
Concept-Oriented Reading Instruction (CORI)	• An evidence-based, science-focused reading program for grades 3–9 that integrates reading and science through classroom activities • Can be used with other content areas • Intends to improve reading comprehension and increase reading engagement	• Significant benefits in three areas: Reading Comprehension, Motivation, and Scientific Knowledge • Stimulates background knowledge and query • Organizes graphically and identifies story structure • Improves the effectiveness of the teaching and learning process	• Classroom management • Teaching material, media, and approach • Teachers must build motivation for info text • Match texts to student abilities • Setting real world purposes for reading • Multicultural content	• Engaging students in reading through using content-area goals during reading instruction • Organizing opportunities for students to collaborate and learn from text • Relating text to background knowledge • Connecting reading to experience	• Adolescent Literacy review protocol • What Works Clearinghouse (WWC) evidence standards	•WWC identified 48 studies of CORI published 1989-2009 with only 5 studies within the scope of Adolescent Literacy protocol. None addressed ELLs. •Guthrie et al. (1998) •Guthrie (2004 & 2007) •Azis (2015)

Reading Apprenticeship Across the Disciplines (RAAD)	• Created by WestEd through a U.S. Department of Education grant (2015-2018) • Uses explicit instruction and explanation of textual meaning with content subjects' objectives to improve language proficiencies and academic success • Promotes a 4-dimensional approach to teaching and learning: personal, social, cognitive, and knowledge	• Improves students' knowledge, strategies, and confidence to become more • effective readers • A powerful framework for literacy development across all subject areas • Students build skills for a better understanding of complex, subject-specific texts	• Teacher buy-in and ownership are key in implementing essential instructional change • Sustainability and amplifying the extent to which teachers report implementing RAAD practices	•Teachers and students work in harmony and reflect on mental processes to understand texts •Building students' confidence to become more strategic and independent readers •Supporting students' discovery, understanding of various disciplinary texts and genres •Guiding student to enquire, explore, and enhance their reading skills	•State Standardized Assessments •Degrees of Reading Power (DRP) •Metacognitive Awareness of Reading Strategies Inventory	•WestEd (2004) •Mehdian (2009) •WestEd (2016)

Promoting Adolescents' Comprehension of Text (PACT)	•A research-based approach to improve teachers' instructional methods for promoting text comprehension •Consists of four research strands: Intervention Design Experiments, Experimental Cognitive Studies, Motivation Studies, and Reader Performance Studies	•Improved outcomes in reading comprehension, content attainment, and sustained content and vocabulary knowledge at multiple points of assessments •Instructional practices are well aligned with best practices for teaching ELLs •With appropriate modifications, PACT can yield positive outcomes for ELLs	•Success depends on class levels of English academic language proficiency •Persuading content-area teachers to learn and implement new strategies for building background knowledge, teaching academic vocabulary, and fostering critical reading and knowledge exploration •School implementation of evidence-based practices	•Improve cognitive processes associated with reading comprehension to identify potential targets for intervention •Engage and motivate students to enhance their reading comprehension outcomes •Integrate and apply new instructional strategies to develop and test the efficacy of interventions for students with reading comprehension difficulties	•AIMSweb Maze CBM Reading Comprehension •ALI (Adolescent Literacy Inventory) •Content/background knowledge assessment •Researcher-Adapted Proximal Comprehension Measure •PACT Battery Descriptions document	•Vaughn et al. (2009) •Lesaux & Kieffer (2010) •The Meadows Center for Preventing Educational Risk. (2013) •Wanzek et al. (2015) •Vaughn et al. (2017)

Instructional Conversation (IC)	• An inclusive classroom approach that focuses on teaching through small-group discussion allowing responsive instruction for each student • Supported by cognitive-devel opmental theory and by four decades of multimethod quasi-experime ntal studies • Highly compatible with both the learning sciences literature and cultural historical theory	• Positive effects on ELL students in reading and other areas of academic performance • Ranked highest English language and literacy development approach for ELLs by WWC • The increase in language arts and higher order thinking drive higher performance in math and science through better comprehension of test questions	• Instruction that does not focus on concepts is unlikely to yield conceptual change • Hard to compare the effects of ICs in relation to other viable teaching methods • Sustainability of conceptual effects of IC over time	• Teaching practices sensitive to language and literacy development can aid ELLs' learning potential • Assistance provided in focused small group learning experiences is pivotal to ELLs • Mediated learning activities will promote higher-order thinking skills that contribute to improvement in reading comprehension and other subject areas	• WWC Standards • States' Standardized Tests • Instructional Talk Assessment Tool	• Tharp & Gallimore (1988) • Saunders (1999) • Bransford et al. (2005) • Adesope et al. (2010) • Duschl & Hamilton (2011) • Rader-Brown & Howley (2014) • Tokuhama-Esp inosa (2014)

Curriculum-Based Language Assessment (CBLA)	• A less discussed approach but a viable alternative to traditional assessment especially when the impact of language differences on academic performance is considered • Uses curriculum framework and content to measure student's language intervention needs and development	• Analyzes local curriculum to determine student's instructional needs • Investigates the efficacy of language skills and strategies used by students during school-related activities to determine types of curricular adaptations necessary to achieve success • Can be used to gather vital information about culturally and linguistically diverse students' language for learning content subjects	• Potential linguistic and content biases associated with word-based assessment of content subject skills • Not easy to determine whether poor performance by culturally and linguistically diverse students reflects academic difficulty or a linguistic difference	• Review classroom curriculum, instruction, and learning materials for linguistic and content bias that might hinder learning in content areas • Design culturally and linguistically appropriate lessons and materials to teach targeted content concepts • Simplify the language but not the concepts while assessing ELLs • Integrate nonlinguistic modes of presentation by using animations, visual examples, and touch-screen computer technology • Advocate assessment accommodations for ELLs	• Observational/Rating Scales • Reading comprehension and fluency language arts activities based on story passages • Head Start curricular-based vocabulary • Storybook writing	• CBLA approaches to bilingual students has not received extensive coverage in the literature • Nelson (1994) • Cline (2003) • Caesar (2005)

Self-Explanation Reading Training (SERT)	•Coalescing self-explanation with instructions to use reading strategies while explaining text •Generating inferences to better understand low-cohesion content subject texts •The automated version of SERT, known as iSTART, uses animated agents to help learners practice how to use self-explanation while reading content subject text	•Designed to improve inference making •Helps readers to more effectively explain text	•Content subject textbooks could have cohesion gaps, posing additional hurdles for ELL students •Students with less knowledge about the domain struggles with poorly written text •Readers who do not possess appropriate linguistical skills generally fail to make the inference and understand the concepts	•Comprehension monitoring •Paraphrasing •Elaboration •Predictions •Bridging	• Prior knowledge test • Nelson Denny reading skill test	•McNamara (2004) •Magliano et al. (2005) •O'Reilly et al. (2006) •Allen et al. (2015)

As shown in Table 1, each of the pedagogical strategies listed in Table 1 has its own benefits and challenges. The common goals of these strategies are to: (1) provide proper assessment methods for ELL students, (2) implement a framework for their literacy development across all academic subjects, (3) improve teaching efficacies and drive students' competence in test performance using several disciplinary texts and genres, and (4) promote collaboration between teachers and their culturally and linguistically diverse ELL students. There is no "one size fits all" strategy. Each school should design and implement a strategy that will optimize the teaching processes of ELL students and improve their learnings. Aligning such strategies with the state's requirements and guidelines set by the federal government is paramount to improving teacher preparation and reducing achievement gap between ELL students and their English-proficient peers.

4. Implications – How to Provide High Quality Teaching and Effective Learning Experiences Using STREAM

One of the greatest challenges hindering the ability of ELL students to perform well in content subjects at the appropriate grade level is perhaps the lack of sufficient vocabulary development. Identifying ELL students who are at risk of failing STEM subjects and providing preventive measurements by integrating Reading instructions can have positive impact on their academic outcomes and learning. Hence, the author of this study recommends implementing the following four plan improvements in all classroom settings: 1) Categorization, 2) Pre-Referral and Referral Practices, 3) Assessment Practices and Eligibility Decisions, and 4) Instructional Interventions.

4.1 Categorization

Teachers should use a variety of tests to identify factors influencing the outcomes of language proficiency assessments of ELL students. The goal of such tests is to collect a comprehensive and accurate information about students' literacy levels in both English and their native language. Teachers should also determine proficiency of ELL students in STEM subjects and examine any relationship between acquiring a new language and students' outcome in STEM subjects. ELL students come from diverse linguistic and cultural backgrounds. Identifying

students who struggle with literacy in English language and STEM subjects and who may or may not have learning disabilities is highly recommended. The No Child Left Behind Act (NCLB) of 2001 shifted the responsibility of educating ELL students from the federal government to individual states. Each state has developed its own assessment method to categorize and report the annual progress of ELL students in English language and academic subjects. As such, teachers should follow guidelines from their perspective states to implement a robust assessment program that takes into consideration ELL students' literacy in the English language and STEM subjects.

4.2 Pre-referral and Referral Practices

Before referring ELLs to special education, teachers should consider providing testing accommodations, testing modifications, and/or early interventions to students who consistently demonstrate signs of struggle in STEM subjects and reading. Teachers can develop appropriate pre-referral strategies within general education as part of a roadmap that may or may not lead to a formal referral process. This could incorporate consulting with experts in language acquisition in all phases of instructional design, adhering to a consistent referral policy, and conducting comprehensive academic assessment particularly when students appear to be delayed in acquiring their native language as well as English language. It is imperative that teachers consider socio-cultural and socio-economic factors, contextual features, school and program characteristics, and ELL students' learning opportunities during assessment, instructional, and referral phases of the education process.

4.3 Assessment Practices and Eligibility Decisions

Teachers should use creative methods when assessing students' strengths to determine the upper threshold of their potential in comprehending STEM subjects. They can observe ELL students in different settings as part of any assessment and pay more attention to cultural and sentimental considerations, particularly sources of potential conflict and motivation. Furthermore, teachers should give more attention to students' native language and to the role of language acquisition by utilizing the use of cognates whenever is possible. Assessing students' prior STEM knowledge in their first language as well as in English to determine predictors of their academic outcomes can go long way in providing appropriate strategies to bring these students to be on par with their English-speaking peers. Teachers should be cognizant that weak auditory processing skills to comprehend STEM subjects could relate to language acquisition rather than to a processing disorder or learning disabilities.

4.4 Instructional Interventions

There is a growing number of studies in the literature addressing effective instructional interventions strategies and models that blend content subject teaching and Reading (Henry et al., 2014; Short, 2017; Sparks, 2016; Tong et al., 2014). Instigating efficacious content and language-integrated instruction for ELL students should have positive impact on their academic outcomes. Combining STEM subjects teaching and reading comprehension with other English language development activities will help students develop a strong foundation in content subjects and promote their literacy in the English language (Carter et al., 2014; Hakuta; 2013; Turkan et al., 2014).

5. Conclusion

During the last few years, there has been a profound discussion in the field of education highlighting the benefits of integrating Reading to STEM subjects. Specifically, many researchers and organizations attest that there are significant benefits of Reading integration practices for ELL students (Dunn, 2017; Fuhui et al., 2014; Lorey, 2017; Messier & Schroeder, 2014). However, the impact of such practices is not fully understood. The challenge of Reading and STEM integration in public schools include buy-in form various stakeholders and working with professionals from different backgrounds. In addition, STEM teachers do not think they are fully prepared or had the proper training to work with ELL students (Breiseth, 2016; Faltis, 2010; Weinburgh et al., 2014). Teacher preparation programs at colleges of education nationwide lagged behind the needs of providing proper training to their pre-service teachers. Most of the training that these teachers receive related to ELLs' education focuses heavily on decoding and fluency in language arts with an ill-advised expectation that comprehension will develop after ELL students are fluent word readers (Ajayi, 2005; Brown; 2007; Lesaux et al., 2014; Sparks, 2016).

Moreover, the implementation of CCSS has widened the academic gap between ELL students and their English-speaking peers. As a result, school districts have put more burden on teachers and held them accountable to ELL students' progress without providing them with the needed resources (CCSS Initiative, 2017b; Hakuta et al., 2013; Kieffer, 2008; Minicucci, 1996). Schools and educational researchers are now challenged by legislatures at the state and federal levels, parents, and other stakeholders to address the achievement gap and to bring forward creative strategies that can improve the academic progress of ELL students. The author of this study explored how Reading

integration can be a vehicle to engage ELL students in a deeper STEM curriculum. The study articulated recommendations and implementation strategies that can be useful for content subject teachers. Further investigation on the impact of Reading on individual STEM subjects and the most effective strategy for integration is currently underway by the author.

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