Multimodal and Hands-on Strategies to Promote Mathematical Knowledge and Skill Development in Students with a Special Focus on English Language Learners

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Abstract: *The focus of this literature review was to research and report on multimodal and hands-on strategies currently being implemented in mathematics classrooms. Due to the large portion of the student population that are non-native English speaking students, special attention was paid to those strategies that focused on, or showed positive effects for, English language learners. This literature review covers information on technology integration, kinesthetic activities, gestures, writing, speaking, visual representations, and physical manipulatives. The findings of this literature review illuminate many avenues for continued research, such as an integration of two or more of the aforementioned strategies for ELLs, and are noted throughout the review.*

Keywords: *English language learners, mathematics teaching, multimodal strategies, hands-on activities*

This literature review was conducted as a means to gain further insight into multimodal and/or hands-on strategies that promote enhanced student understanding in mathematics, with a primary focus on strategies that promote enhanced mathematical understanding for English Language Learners (ELLs). The keywords used to locate articles were "hands-on activities," "multimodal methods," "mathematics," and "English Language Learners." Using the aforementioned keywords, or a combination thereof, many articles were located. The search showed that much research has been conducted in this area since the adoption of the No Child Left Behind Act (NCLB) of 2001.

NCLB was adopted into legislation on January 3, 2001 and activated July 1, 2002 (NCLB Legislation, 2010). This act was implemented as a means to narrow the achievement gap between low-performing and high-performing students by enhancing assessments, increasing accountability standards for educators, providing funds to schools for innovative programs, as well as other forms of reform (No child left behind legislation and policies, 2011). However, states were left to create their own standards and curricula based upon national standards, which caused standardized assessments to show a decrease in student achievement, further widening the gap (Neill, 2003).

In July 2009 a "[n]ational [c]ompetition to [a]dvance [s]chool [r]eform" (Hamilton, 2009) aptly titled "The Race to the Top Legislation" (RTT) was created to help schools to improve their academic results by competing for grants to promote reformed, innovative classroom practices (Hamilton, 2009). This, too, has flaws in its development and implementation (McNeil, 2012; Ravitch, 2010).

The gaps in student achievement are especially wide between native English speakers and ELLs. As of 2009, 11.2 million students in public and private schools in the United States were

ELLs and this number continues to grow each year (Children who spoke a language other than English at home, 2012). These statistics show the need for immediate reform in the mathematics classroom to improve student performance for all learners, but especially for ELLs.

Mathematics has long been a gategeeper for students; if they perform well they meet with much success and if they do not perform well they are limited in their future career opportunities (Moses and Cobb, 2001; Stone, 1998). For this reason as well as the literature already presented on NCLB and RTT, and additional literature to be presented in this paper, I conjecture the only way to truly improve students' learning and understanding, and thus assessment scores, is to educate mathematics instructors in multimodal teaching strategies and hands-on activities that promote student engagement, interest, understanding, and desire to learn.

The multimodal strategies available to teachers are numerous, but this paper will discuss technology integration, kinesthetic activities, gestures, writing, speaking, and visual models. Some of the aforementioned strategies may seem obvious, however it is the proper use of these strategies that provide the optimum benefit to the students. Hands-on activities will also be discussed herein such as the use of manipulatives; again, the *proper* implementation of manipulatives is the key to promoting optimal understanding.

Multimodal Strategies

Virtual Manipulatives – Technology Integration

With the push for 21st Century skills to be taught in all schools, technology has been at the forefront. However, students' use of technology is not the only skill necessary for the 21st Century. Students also need to be flexible in problem-solving, able to work collaboratively, able to produce and manage knowledge, and effectively communicate (Partnership for 21st Century Skills, 2008). All of these skills can be strengthened through the appropriate integration of technology in and out of the classroom. Freeman (2012) believes “by providing *both* empowering and supportive learning environments with targeted and specific instructional scaffolds, digital technologies can overcome some of the barriers that currently obstruct the progress of ELLs on the road to realizing their potential, their capabilities” (p. 51). Suh, Johnston, and Douds (2008) claim “a technology-rich environment for mathematical learning influences…the nature of classroom tasks, the mathematical tools as a learning support, the role of the teacher, the social culture of the classroom, and equity and accessibility” (p. 235).

HELP math, developed by Digital Directions International, is a “flexible digital learning environment” (Freeman, 2012, p. 53) that provides support to ELLs as they progress through mathematics in grades K-12 and is the first online environment to utilize sheltered instruction (Freeman & Crawford, 2008). HELP math is designed to provide support to ELLs by embedding “sheltered instruction and other research-based strategies directly into a mathematics curriculum” (Freeman, 2012, p. 50). Too often it is not the mathematics, but the mathematical language that prevents students, especially ELLs, from gaining a complete understanding of topics and concepts. Sheltered instruction is a specialized instructional strategy that attempts to eliminate the language barrier by increasing student comprehension; by scaffolding through visual cues, contextual cues, demonstrations, and slower verbal delivery; through vocabulary development; through use of student background knowledge to bridge new knowledge; by linking new knowledge to students’ lives; by promoting collaboration among students; by improving cognitive challenges; and by providing review and assessment of learned material (Freeman & Crawford, 2008). Freeman (2012) believes “teaching math concepts without providing language support is a false opportunity for non-native English speakers to learn math in the U.S.classrooms” (p. 50-51).

HELP math allows teachers to easily differentiate instruction to meet the needs of all learners, not just ELLs, by making the mathematics accessible to all learners (Freeman & Crawford, 2008). HELP math creates this unique learning environment by eliminating cultural and linguistic barriers; helping students reach outside of their zone of comfort (Vygotsky, 1978); using rich multimedia; using constructive, interactive feedback loops; and emphasizing both mathematical and symbolic language (Freeman & Crawford, 2008). This unique environment allows students to develop confidence in their ability to perform mathematics and gain a deep understanding of the concepts that can then be applied to other scenarios, namely real-life problems (Freeman & Crawford, 2008).

The HELP math program was integrated into an enrichment program in a semi-rural Colorado high school as part of a research study to evaluate the effects of the program on ELLs. The study was comprised of fifty ninth- and tenth-grade students who were ELLs and the study aimed to assess students' growth of knowledge and perceived mathematical self-efficacy (Freeman, 2012). Students spent a minimum of 15 hours per week using HELP math for a period of four months. Freeman (2012) found that students who used the HELP math program performed significantly higher on the post-test than students in the comparison group[1] (medium effect size of 0.46). Freeman (2012) also found the amount of time spent using the program affected the students post-test performance[2]; those who spent more than 15 hours saw the greatest gain in mathematical knowledge and ability. Through this intervention Freeman (2012) found students' mathematical performances improved as well as their "perceived math self-efficacy" (p.60).

[1] Freeman (2012) used a comparison group to evaluate her data; she did not include a control group in this research study.
[2] Students were allowed to use the program outside of the scheduled class time (e.g., home, library, etc.).

Texas Instruments created a program titled *TI MathForward,* a program for pre-algebra and algebra, which provides teachers with professional development opportunities, TI-Nspire™ technology for classrooms, and educational support for students (Fincher, 2012). Texas Instruments developed this technology after working closely with the Richardson Independent School District during the 2004-05 school year in an attempt to eliminate the achievement gap present among middle school students (TI MathForward: About Us). This program was launched nationally in 2007 (TI MathForward: About Us). The TI MathForward program is based upon eight research-based components: (1) motivating technology, (2) teacher coaching and professional development, (3) enhanced content knowledge by teachers, (4) integrated curriculum, (5) aligned assessments, (6) additional instructional time, (7) common planning times for teachers, and (8) administrative and parental support (The eight compenents of success).

A research study completed during the 2008-2009 school year in a southeastern US school district found that the implementation of the TI MathForward program in six of their middle schools showed a 25-point average gain among the 8^{th} grade students in the experimental group as opposed to only a 14-point average gain among the 8^{th} graders in the control group (Fincher, 2012). This school district also faced a large amount of teacher attrition before the implementation of the program (nearly 50% of their staff yearly) and only one teacher chose to leave the district at the end of the first school year the program was adopted (Fincher, 2012). This school district expanded the program in the 2009-2010 school year to include all of the 7^{th} and 8^{th} students in ten of their middle schools; at the end of the year 7^{th} graders showed two-years growth in academic skills and 8^{th} graders showed three years growth as compared to the students in middle schools not participating in the program (Fincher, 2012). The most powerful evidence to substantiate the use of the TI MathForward program for ELL students is the amount of growth experienced by ELLs in this district; the ELLs who participated in this program increased their mathematical knowledge by four to five years (Fincher, 2012).

Interactive Whiteboard Technology (IWB) has been shown to produce positive results in student performance for all students, including ELLs. IWB consists of a large interactive whiteboard connected to a projector and computer (also known as a SMART Board). A research study evaluating the effects of IWB also used an electronic slate linked to the white board (passed from student to student) which allowed students to draw, write, or respond to questions from their desks (López, 2010). A research study was conducted in an urban school district in Texas to evaluate if the use of IWB could narrow the achievement gap between ELLs and regular students (López, 2010). Three schools from the district were selected to participate in the study with a total of three 3rd grade teachers and four 5th grade teachers[3] comprising the treatment groups; two comparison groups were used and comprised of regular and ELL students in traditional classroom settings (López, 2010). López (2010) found the pass rate of third grade ELLs in the treatment group on the Texas Assessment of Knowledge and Skills (TAKS) to be 82.4% as compared to a pass rate of 69% in the comparison group. The pass rate of fifth grade ELLs in the treatment group on the TAKS was 88.9% as compared to 66% in the comparison group (López, 2010). Although these are the findings from one research study, with specially chosen teachers, it shows the benefit of IWB. Further research on the effects of this interactive digital technology in the long term would certainly provide more credible and generative findings (López, 2010).

[3] The teachers were each chosen by the principals of the schools and were well-performing teachers (López, 2010).

HELP math, the TI MathForward, and IWB programs are just three of many technology resources that are available to help students gain a deeper mathematical understanding while simultaneously building language and comprehension skills. However, teachers must understand that technology will only become a beneficial tool to enhance student success when it is used in context, to enhance mathematical understanding, to connect mathematical ideas, to incorporate multiple representations, and when it is used along with classroom practices and not in place of them (Suh, Johnston, & Douds, 2008).

Kinesthetic tools

Allowing students to move around while learning new concepts provides a sensory approach that will help them to understand new information (Young & Marroquin, 2008). Since physical activity causes more of the brain to be active than non-physical activity more learning is possible (Jensen, 2001). Young and Marroquin (2008) completed a research study implementing outside space near the school's playground. Young and Marroquin (2008) drew large mathematical representations (e.g., geometric figures, clock, hundreds chart, number line) that were used to teach various concepts to elementary school students (pre-K through 5th grade). Young and Marroquin (2008) found greater risk taking attempts among the students, increased student engagement, and student use of the drawings outside of class time (i.e., during recess). Teachers also reaped benefits from the "playground drawings" such as increased student success, development of lessons requiring more cognitive skill use, and increased attention paid to learner-centered activities (Young & Marroquin, 2008). The lessons that incorporated the real-life drawings especially benefitted ELLs by creating a stronger connection to mathematical and academic vocabulary and an improved understanding of abstract concepts (Young & Marroquin, 2008).

Gestures

Many people talk with their hands (their hands move while speaking) and it is not uncommon to see teachers "talking" with their hands as they teach in front of the classroom. Shein (2012) set out to research whether or not the visual cues portrayed by teachers' use of hand movement while verbalizing content knowledge created an enhanced learning environment for ELLs and thus improved their understanding of mathematical content knowledge. Kendon (2007) believes that the use of gesture and speech provides a multimodal avenue for the thinking, learning, and teaching of mathematics. Shein (2012) chose to monitor and evaluate gestures that promoted student thinking and improved their ability to find and repair mathematical errors in their own work. The gestures examined in this study were "any actions or movements made by the teacher or students that pertain to the mathematical tasks at hand" (Shein, 2012, p. 185). The specific gestures being evaluated were split into three categories: (1) pointing – when a finger, hand, or writing object was used to bring attention to a person, place, or object that may or may not have been apparent in the verbal communication; (2) representational – movements to elaborate on abstract or concrete ideas communicated verbally; and (3) writing – writing on a worksheet, board, etc. while simultaneously speaking about a concept (Shein, 2012).

ELLs benefit from the use of gestures by teachers, and *to* teachers, as they may not possess the mathematical vocabulary required, but do possess the knowledge and understanding; gestures provide teacher-student, student-teacher, and student-student communication (Shein, 2012). Shein (2012) completed a relevant case study of a fifth grade teacher in a K-5 school in South Central Los Angeles as well as six purposefully chosen (Patton, 2002) students in her classroom. The school identified 95.5% of its students as Latino or Hispanic and 99% of the students spoke Spanish in their homes (Shein, 2012).

Shein (2012) paid particular attention to whether or not the teacher recognized students' gestures and if she responded to the students using both verbal language and gestures. Shein (2012) found the teacher's return gesture to be an essential method of revoicing – rephrasing the question posed. Students were able to communicate their understanding, were more engaged in their learning, and appeared more confident in their abilities when gesturing was used as a mode of communication in parallel with speaking (Shein, 2012). It is important to understand, however, "this multimodal revoicing practice would not be possible if she [the teacher] had not established a classroom norm that fostered and legitimized a form of communication that infused oral, visual, and gestural modes" (Shein, 2012, p. 216). Although this study is qualitative in nature and does not provide statistical evidence of improved student performance, nor is it generative to other classrooms, it does shed some light on another mode that can be used to improve student understanding. Further research in the area of gesturing using quantitative methods could provide useful information in the mission to narrow the performance gap between native and non-native English speakers.

Writing

Although writing has been mentioned as being an integral part of gesturing and digital technologies, it is also a very useful form of communication to improve the understanding of all learners, whether used in conjunction with other modes of communication or used independently. As students work collaboratively in groups to learn new concepts or to problem-solve, the writing they produce during this time allows teachers to follow their work and easily determine any misunderstandings the student(s) may have (Casler-Failing, in press).

Swanson (2010) used writing in her multi-age classroom, in which more than 50% of her students were ELLs, as a way to help students understand integers. Students worked collaboratively to create a visual model of integers used in the real-world (e.g., a picture of a cliff, water, and a diver going below the water) and were then asked to create story problems that could be answered with or without the use of the visual representation (Swanson, 2010). Although some of the student groups required scaffolding to create coherent, meaningful word problems, the students were confident and engaged; any mathematical errors found were identified and discussed to ensure student understanding was achieved (Swanson, 2010).

Speaking

The greatest factor hindering student achievement among the ELL population in the United States is the language barrier between their native language and the English language used in schools (Slavit and Ernst-Slavit, 2007; Roberts, 2009; Chval and Chavez, 2012; Demski, 2009). ELLs that enter US schools with mathematical understanding possess that understanding in their native language. Although these students may be capable of performing computations extremely well, they lack the requisite skills required to engage verbally in the learning community due to the language barriers. The onset of the Common Core State Standards holds teachers accountable for their students' successes, or lack thereof, and it is more imperative than ever to help ELLs gain the skills required to be successful in every classroom, including the mathematics classroom.

The eight overarching standards embedded in the Common Core State Standards for mathematics are that students will: (1) make sense of, and persevere, in problem-solving; (2) be able to use abstract and quantitative reasoning; (3) be proficient in constructing meaningful arguments as well as critique others' arguments; (4) model mathematics; (5) use mathematical tools appropriately; (6) be precise in their answers and responses; (7) be able to notice patterns and make use of them in problem-solving; and (8) be able to recognize repeating structures and apply the knowledge to other scenarios (Common core state standards for mathematics, 2012). After reading these goals it is apparent that ELLs need to have a solid understanding of the English language in order to achieve success and eliminate the gap between native and non-native mathematics students' performance on local, state, and national assessments.

The major hindrance to ELLs is the existence of two forms of language in the classroom, academic and social (Slavit and Ernst-Slavit, 2007). Academic language is the language one uses in the classroom to communicate and learn new knowledge and/or skills whereas social language is what is used to communicate verbally in a social setting (i.e., conversation between friends); students may need five to seven years to understand and use academic language appropriately (Slavit & Ernst-Slavit, 2007). Due to ELLs limitations on their academic language skills, some teachers use low-level questions to asses students' understanding rather than using gestures or other representations in parallel with the language; this absence of higher-level language hinders their ability to acquire the necessary language skills (Chval & Chavez, 2012). In order to develop academic language in the mathematics classroom students need to learn to speak both social and academic language and participate in experiences unique to the mathematics curriculum (Roberts, 2009).

Mathematics teachers of ELLs need to represent mathematical language in multiple contexts while verbalizing the material (e.g., drawing pictures, modeling, etc.) in order to afford their students the greatest amount of success (Roberts, 2009). Mathematics teachers need to develop ELLs use of language in the context of problems to help connect meaning to the words through enhanced mathematical tasks that engage students (Chval & Chavez, 2012). A method for helping ELLs break through the language barrier is to relate new vocabulary to their native language by making connections among the words (Demski, 2009). The use of cognates – a word that has a similar meaning and pronunciation in different languages – has been found to be an effective strategy in connecting native languages to academic language for ELLs (Gómez, 2010).

The use of cognates in Structured English Immersion (SEI) lessons can be extremely beneficial to ELLs, especially when the lessons incorporate multiple modes of learning such as content, language, connecting prior knowledge, modeling, use of manipulatives, use visual representations, multiple representations of techniques and strategies, and collaborative work (Gómez, 2010). The use of cognates in the classroom not only benefit and engage ELLs, but can also be useful in language acquisition for native English speakers participating in foreign language classes; in this type of setting every student is given the opportunity to succeed on many different dimensions (Gómez, 2010). In order for mathematics lessons to be successful for all students, especially ELLs, they must contain challenging content, build knowledge and understanding of concepts, and develop proper academic and social language usage (Swanson, 2010). English language learners must also be patient and understanding of the fact that "[t]eachers can demonstrate to language learners [through the use of cognates] that their academic knowledge in their primary language can accelerate their learning in English" (Gómez, 2010, p. 474). Gomez (2010) also integrates writing with his use of cognates by having students make tables of the cognates learned for each unit to activate prior knowledge and allow students to gain confidence in their language skills by having a quick reference readily available to them when needed (see Figure 1).

FIGURE 1

Using the cognates strategy to activate prior knowledge allowed a recent Mexican immigrant to see that she already knew many English words.

Cognates strategy: activating prior knowledge		
1. Vocabulary	Vocavulario	hablar o pronunciar las palabras
2. Park	parque	lugar formado por pasto y juegos
3. Part	Parte	es una pieza de alguna cosa
4. computer	computadora	un aparato científico
5. cube	cubo	figura que todas sus caras son cuadradas

(Gómez, 2010, p. 473)

Visual Models

Visual representations are important tools in helping ELLs gain understanding and apply new knowledge in the mathematics classroom (Swanson, 2010). A mathematical concept such as statistics, with the many types of data representation available to teachers, would be nearly impossible to communicate to ELLs, as well as native speakers, if the content could not be disseminated in multiple modes. Teaching students to understand the difference between line plots, line graphs, bar graphs, histograms, etc. would require extensive verbal skills on behalf of the teacher and the students. However, when teaching students verbally about the topics while using visual representations, the students are able to make connections and gain a deeper understanding of the different uses of each type of representation. Swanson (2010) taught integers using a picture of a cliff, water, boat, and various other objects with a number line vertically positioned on the picture[4]. By looking at the picture, students were able to understand the water level was at "0" and anything in the water was "in the negative area" of the number line, whereas the cliff, boat, and airplane were "in the positive area" of number line (Swanson,

[4] The picture can be viewed on page 518 of the Swanson (2010) article.

2010). The picture also afforded the students an opportunity to "see" new vocabulary words as they learned them (e.g., positive, negative, opposite) (Swanson, 2010).

Visual representations do not need to exist only in mathematics lessons – they can become part of the mathematics environment. Every classroom is full of artifacts, chalkboards and/or whiteboards, bulletin boards, etc. Labeling these items can aid in helping ELLs gain understanding of the English language. During classroom instruction, if teachers use vocabulary that is represented in the classroom they can point it out, creating a visual connection to the verbal word (Cipriano, 2011).

Hands-On Strategies

Physical Manipulatives

Physical manipulatives have long been a fixture in mathematics classrooms; items such as Cuisenaire rods, base ten blocks, and games have been used to help students connect abstract concepts to concrete understanding (Özgün-Koca & Edwards, 2011). However, items such as M&Ms or Skittles[5] can also be considered manipulatives; when physical objects are used in the process of learning new concepts in a mathematics classroom they are deemed "manipulatives." Özgün-Koca and Edwards (2011) completed a research study to determine whether the integration of physical and virtual manipulatives enhanced mathematical understanding for sixty 8th grade algebra students in a Midwestern US school. This study was conducted under the assumption that students create mental schemas from the use of the physical manipulative that carry over to the virtual manipulative, which ultimately strengthens their understanding of the concept (Özgün-Koca & Edwards, 2011).

[5] The author has used these candies as manipulatives in her classroom to collect data during a statistics unit.

In the study by Özgün-Koca and Edwards (2011) students used dry spaghetti to create a best fit line on a given a coordinate grid, with pre-plotted points, using prior knowledge of the concept. This lesson integrated kinesthetics (moving the spaghetti around) with a hands-on activity (touching the spaghetti and coordinate grid) to provide a rich, authentic experience. After completing the hands-on portion of the lesson, students opened a saved document in their TI-Nspire™ calculators which depicted a similar coordinate grid and pre-plotted points with a best fit line drawn in (Özgün-Koca & Edwards, 2011). Students used the tool available in their calculator to show the value of the residuals while they moved the best fit line up and down and/or changed its angle to the y-axis (Özgün-Koca & Edwards, 2011). After collecting a brief survey from the students (only 41 of the 60 students responded) Özgün-Koca and Edwards (2011) found 35 students preferred the virtual manipulative due to the instant feedback provided by the calculator and 6 students preferred the physical spaghetti because they could actually touch it and the students felt the use of the spaghetti in the lesson provided a real-life experience for them. Although this was a qualitative study that does not possess concrete statistics to support the integration of physical and virtual manipulatives, "the combination of concrete and virtual experiences helped students more effectively by serving both kinesthetic and visual learners" (Özgün-Koca & Edwards, 2011, p. 400).

Conclusion

This literature review attempted to inform the reader of the many different strategies that help to promote mathematical literacy, knowledge, application, and skills. Many modes of instruction were presented along with the findings of research studies that promote the use of multimodal instruction. It seems as though every educational news story on television, in the newspaper, or on the World Wide Web speaks to the deficiencies of our nation's Science, Technology, Engineering, and Mathematics (STEM) curriculum. This paper was written to inform others of the need for these methods and strategies to improve the mathematics curriculum in the United States for all students, but it appears ELLs have the most to gain from the implementation of any/all of these strategies. As reported on page one of this paper, there are currently 11.2 million ELLs in this nation that rely on our teachers to help them achieve success in mathematics while simultaneously learning how to speak the English language. This is not an easy feat for any person, and often the teachers and the students both become frustrated, but with professional development opportunities, administrative support, and adequate resources every person can be successful.

Lack of mathematical fluency and access to higher level mathematics has long prevented students from achieving their career goals, thus possibly limiting their economic potential (Roberts, 2009); "[f]ull citizenship is dependent upon students being mathematically literate" (Roberts, 2009, p. 35). ELLs come to this country for a better life and increased opportunities – those opportunities should not be limited by their lack of mathematical achievement. Every student is capable of learning and succeeding in school, however every student is unique. Those unique characteristics must be known and all students' needs must be met to ensure they are receiving the best education possible.

After reading this paper it should be apparent that further research is necessary in the area of multimodal instruction in mathematics to enhance ELL instruction, however the design of technological applications must be carefully considered before being implemented and student effects should be carefully monitored (Özgün-Koca & Edwards, 2011). Teachers' use of multimodal strategies must be "purposeful…[and] target the development of language and mathematics for the ELLs in their classroom" which is not a task to be taken lightly, it is a task that "requires thoughtful conversations and planning" (Chval & Chavez, 2012, p. 265).

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