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Emerging Bilinguals Future Teachers' Digital Behavior in ONLINE Pre-Calculus Class: Mixed Methods Study

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Abstract

The educational landscape is becoming a digital learning environment. Students in today's digital world draw from multiple sources of information; from hypertext, videos, social media, to video games and internet searches (Luke, 2005). Emerging bilinguals, individuals learning two languages at once, who use software written in English have a passive relationship with the computer when software is not in their native language. They feel that this educational software belongs to another culture. This paper will present findings from a study with emergent bilinguals' engagement in a fully online pre-calculus course. The authors utilized the Cultural-Historical Activity Theory to describe how emergent bilinguals (perspective teachers) created authentic bilingual learning environments and improved their self-efficacy for mathematics. This study utilized Activity Theory to explicate the complex digital practices of emergent bilinguals while engaged in an online mathematics course. This mixed methods study was conducted over four semesters at a university on the U.S.-Mexico border. Data collected from demographic survey, class forum questions, daily logs with snapshots, self-efficacy surveys, and emails as well as face-to-face interviews, was analysed through a constant comparison method. Two tensions emerged from the findings, the importance of learning English and encountering unfamiliar Spanish dialects or translations. The results of this study demonstrated that emergent bilinguals mediated several forms of translators and culturally relevant videos for meaning making and to make cognitive connections with the topics in an online mathematics course. They further developed agency in creating an equitable educational digital space where they developed mathematical biliteracy.

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Introduction

According to Lev Vygotsky (2012), humans learn through discourse and social contact; in online environments, this could be through email, course forums, texting, webinars, and blogs (Harasim, 2012). Griffiths et al. (1994) opined that cultural and language adaptation of software for non-English cultures could be beneficial. These researchers felt that software written in a student's native language could benefit students socially, educationally and financially. Translating math software can be yet another tool for oppressed students to create equitable learning opportunities.

Studies which investigate translanguaging, best practices, and literacy in teaching mathematics for emerging bilinguals are numerous in the educational literature (Esquinca, 2011; Moschkovich, 1999; Moschkovich, 2007; and Remillard, & Cahnmann, 2005; Tahar et al., 2010). Self-efficacy and learning attitudes research is also an area studied in great depth (Canfield, 2001; Di Martino, & Zan, 2010; Freeman, 2012; Muilenburg & Berge, 2005; Reed, Drijvers, & Kirschner, 2010; Rivera, & Waxman, 2011; Spence, & Usher, 2007; Tahar et al., 2010). As more universities are offering more and more online mathematics courses, the necessity to study how emerging bilinguals engage with technology in a mathematics class and how this affects their self-efficacy is significant. This mixed-methods study focused on how emerging bilinguals utilized their digital practices to create equitable bilingual educational environments in an online pre-calculus course.

Theoretical Framework

Bandura (1977) defined self-efficacy as a belief in one's ability to perform at a certain level. Students with a higher self-efficacy were found to have better test scores and achieved greater success in their mathematics classes (Freeman, 2012; Kitsantas, Cheema, & Ware, 2011; Rivera & Waxman, 2011). These studies implemented factor analysis on student surveys and questionnaires to quantify and measure self-efficacy and attitudes towards mathematics. Rivera and Waxman (2011) found that self-efficacy influenced emergent bilingual students' resiliency in a mathematics classroom. A positive self-efficacy had a positive effect on the math course, whereas a negative self-efficacy had a negative effect.

Moschkovich (2007) found that language was an important aspect of a positive attitude and self-efficacy. Students were found to improve mathematical conceptual knowledge when they were allowed to use their preferred language. When a Latin@ immigrant performs basic arithmetic calculations, they mentally perform these calculations in the language of instruction, which for many was in Spanish (Moschkovich, 2007). Moschkovich (2010) opined that mathematics researchers should be more concerned with how language use relates to mathematical learning than "with making subtle distinctions among different

language practices" (p. 130). Using language in learning mathematics may be far more evident in an online environment, where a student may have to find the meaning of mathematical terms and vocabulary by searching the internet.

This mixed methods study was designed to explore how emergent bilinguals (perspective teachers) engage in an online mathematics course through the interaction of the course rules and procedures, software and internet capabilities, and the sociocultural environments created in online classes.

The open-ended research questions are:

Research Question 1: How do undergraduate English Language Learners engage with an online math course?

a. How do emergent bilinguals make meaning of mathematical terminology using digital activity systems?

b. How does language meaning making with an intelligent tutoring system affect emergent bilingual's progress with an intelligent tutoring system?

Research Question 2: Do digital meaning making practices such as email, course forums, texting, translating software, YouTube videos, and blogs impact self-efficacy?

ALEKS software

Online mathematics courses have evolved from professors posting PowerPoint presentations or lecture notes onto web-based learning management systems to the utilization of intelligent tutoring systems which can be translated into Spanish (Engelbrecht & Hardning, 2005; Harasim, 2012). In today's online courses, emergent bilinguals have access to digital media, online translators and intelligent tutoring systems that can be translated into their native language for meaning making. One such intelligent tutoring system is ALEKS.

ALEKS unveiled English-Spanish mathematical courses in June 2008. The translations provided by ALEKS were written in native new world Spanish by human translators (ALEKS, 2017). Although the entire program can toggle back and forth from Spanish to English, the videos that are linked to the course within the software are not translated, nor are they subtitled in Spanish. ALEKS is not the only intelligent tutor on the educational market which can be translated. Practitioners and developers of online mathematics courses have a variety of software. from which to choice in creating their online courses. ALEKS is based on techniques from artificial intelligence, utilizes conditional probabilities and if based on Knowledge Space Theory. Knowledge Space Theory uses combinatorics and stochastic processes to accurately determine the prior knowledge of topics a student has mastery of, called the student's knowledge state (Falmagne et al., 1990). The creators of ALEKS, software engineers, computer scientists,

and mathematicians describe it as an artificially intelligent assessment and learning system. ALEKS is built on sophisticated concepts from combinatorics and stochastic processes in forming distinct knowledge states for students (Falmagne, et al., 1990; ALEKS, 2016). This is evident when one student is working on solving exponential equations while another student is discovering the concept of slope for a linear equation. Each student follows a unique learning path as determined by their knowledge state or zone of proximal development (Vygotsky, 1986). The constructivist basis of ALEKS can be traced to Vygotsky's Zone of Proximal Development and activity theory (Leont'ev, 1978; Vygotsky, 1960, 1986). Through Markovian procedures and conditional probabilities, ALEKS quickly and accurately determines which topics a student has mastery of. The software then generates unique questions for each student based on their previous answers. The software creates a learning path from the probability that the student will answer the questions for the next topic correctly (Falmagne et al., 1990). The set of all questions for one course on ALEKS is called the domain. The collection of sub-domains is called a "knowledge state". Once a knowledge state has been determined, ALEKS provides each student with an individual learning path that the software has determined is the best fit for the student's current knowledge state. Students can follow the learning path which ALEKS provides or they may choose a different path by selecting other topics and follow the learning path that begins with this new topic, so long as the student has mastered all prerequisite material. As a student works through the course, ALEKS periodically assesses the student to ensure that topics are retained in their long term memory.

There have been many studies on the effectiveness of ALEKS improving college mathematics course placement, standardized test scores and pass rates (Fine, Duggan, & Braddy, 2009; Golberg & Mckhann 2000; Hagerty & Smith 2005; Hagerty, Smith & Goodwin, 2010; Hampikian et al., 2006; Hampikian et al., 2007; McClendon & McArdle, 2002; Spradlin, 2011; Taylor, 2008; Xu, Meyer, & Morgan, 2009). These studies provided quantitative analysis and found ALEKS to be effective in improving placement test scores, standardized test scores, and class grades. Three of the studies (Hampikian et al., 2006; McClendon & McArdle, 2002; Xu, et al., 2009) provided qualitative data on student's attitudes and self-efficacy in their research. These studies found that most participants felt that ALEKS was beneficial in helping them better understand the mathematical content.

None of these studies identified emergent bilinguals as participants nor did these studies address how language affected participants' engagement with ALEKS. Emergent bilinguals are a population that has been widely ignored by research in the effectiveness of intelligent tutoring systems, such as ALEKS. The U.S. Hispanic population accounts for a little more than half the total U.S. population growth from 2000 to 2014, roughly 54% (Krogstad, 2016).

Cultural-Historical Activity Theory (CHAT)

Vygotsky, Leont'ev, and Luria, are credited with developing Cultural-Historical activity theory (CHAT), also referred to as Activity Theory (Blunden, 2010; Engeström, Miettinen, & Punamäki, 1999). Yrjö Engeström developed what is considered the third-generation of CHAT, in which the unit of analysis is a network of activity systems and the inherent tensions that arise in the learning process (Blunden, 2010; Engeström et al., 1999; Engeström 2001). In activity theory the unit of analysis is the activity by which the subject is mediating tools or artifacts in the realization of a goal; the goal is referred to as the object (Engeström et al., 1999; Lantolf, Thorne, & Poehner, 2015; Yamagata-Lynch, 2010). The activity in which the subject engages is additionally influenced by the procedures which govern the social community in which the subject resides and by the tasks, or roles, of that community (Engeström et al., 1999; Yamagata-Lynch, 2010). Activity theory is consistent with ethnographic studies that focus on behavior and activity to describe and explain human experiences.

Methodology

This study utilized an embedded-exploratory design where findings emerged from the analysis of qualitative data which was supported by findings from quantitative data (Creswell & Clark, 2007). The embedded-exploratory methodology utilized in this study provided the researchers access to the lived experiences and digital practices of several emerging bilinguals participating in an online pre-calculus course over three semesters. An IRB proposal was submitted and approved for this study. This study was conducted in an online pre-calculus course over four semesters, from 2014 through 2016. Through a CHAT framework, the author employed an embedded-exploratory design to analyse qualitative data supported by quantitative data.

Analysis of the multi-layered qualitative data through an activity theory lens illuminated the complex relationships emerging bilingual developed between the mathematical content, their academic language proficiency, and online sociocultural environments. Emergent bilinguals were able to make cognitive connections between prior knowledge learned in their native language, Spanish, and new topics learned in English. However, tensions arose with emergent bilinguals' attitudes towards learning new material in English and their self-efficacy. These tensions lead the authors to develop an activity system diagram to fully describe emergent bilinguals' digital learning environments.

Setting and Data sources

Data was gathered from one demographic survey, two self-efficacy surveys, weekly course forum questions, weekly logs with screen shots, email interviews with focus groups, and face-to-face interviews

with two key-informants, in an attempt to understand the digital practiced of Emerging bilinguals participating in an online pre-calculus course. As we mentioned in the beginning of this paper, geometric explanations of mathematics-based pedagogical recommendations are usually more convincing than the usual algebraic ones, and the move convincing the explanations, the more willingly the teachers will follow them.

Findings

An activity system was developed by the authors of this study to explicate emergent bilinguals' mediation of the translation capabilities in an intelligent tutoring system and an online translator (Figure 1). Emergent bilinguals made meaning of English vocabulary and mathematical lexicon by mediating the software translation capabilities and online translators. Figures 1 and 2, articulates the complex actions of emergent bilinguals within a sociocultural educational environment. Emergent bilinguals followed course procedures (Rules), were engaged in the online pre-calculus course (community), and were meaning consumers while mediating the online translators (mediating artifacts). Figure 1 displays the six components of Engeström's (1999) activity system with arrows to indicate the tensions between each component that were encountered in the online pre-calculus course. These tensions were the unfamiliar Spanish dialects or translations emergent bilinguals encountered.

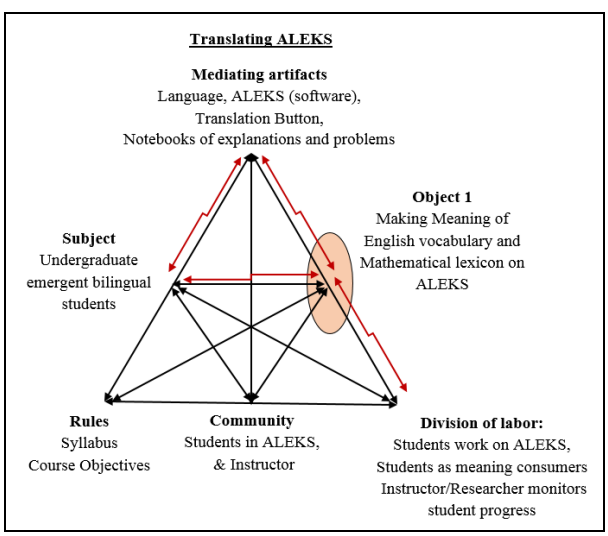

Figure 1. Activity system for translating online ALEKS software with tensions depicted by red arrows.

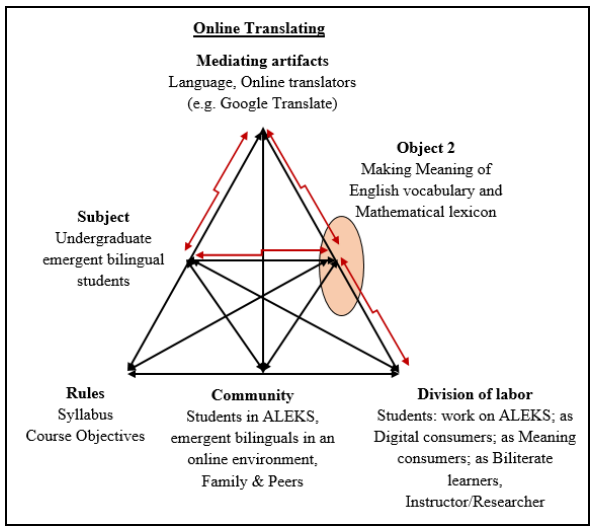

Figure 2. Activity system for online translating with tensions depicted by red arrows.

A two-way multivariate analysis of variance was conducted on the Mathematics Self-Efficacy Survey (MSES) pre- and post-surveys (N=13) with the two independent variables being the MSES survey scores and translating the software. A representative group of ten English-dominant students was used to compare with emergent bilingual key informants. The analysis showed that there was no statistically significant interaction nor a correlation between the MSES scores and whether a student translated the software with their self-efficacy, the dependent variable ($F(18,5)=0.316, p=0.968$; Wilks' $\Lambda=0.468$). A two-way multivariate analysis of variance was also conducted on the Mathematics and Technology Attitudes Scale (MTAS) pre- and post-surveys (N=13), with the two independent variables being the MTAS and whether a student translated the software or not. The analysis showed that there was no statistically significant interaction between self-efficacy, the dependent variable, with mathematics and technology and whether a student translated the software or not, $F(20,2)=0.326, p=0.961$; Wilks' $\Lambda=0.039$). There was, however, a statistical correlation between translating the software and individual survey items. The findings discussed next result from descriptive analysis.

Emergent bilinguals in this study developed confidence in their mathematical skills when they utilized their digital literacies to find solutions to the online practice problems. Emergent bilinguals believed that they could master a computer program needed for school. Their self-efficacy in the use of smart devices also increased at the end of the semester. One Spanish-dominant participant reflected the sentiments of many participants when she stated: "I feel confident [with ALEKS, the online software] and look forward to what

is next." Emergent bilinguals utilized their digital meaning making strategies to show a marked improvement in their self-efficacy.

The MTAS showed that emergent bilinguals increased their self-efficacy on several key items while their English-dominant counterparts' self-efficacy decreased (Figure 3). Translating the online software and utilizing online translators allowed emergent bilinguals to make meaning of English vocabulary and increased their attitude towards class required computer programs. Emergent bilinguals developed agency in their mathematical education and increased their mastery of the mathematical topics through their digital practices. For emergent bilinguals, this translated to mastering any computer program required for school. Finally, emergent bilinguals developed a complex network of digital activities that allowed them to learn mathematics in both English and Spanish, leading to their belief that they do in fact have a mathematical mind (Item 9, Figure 3).

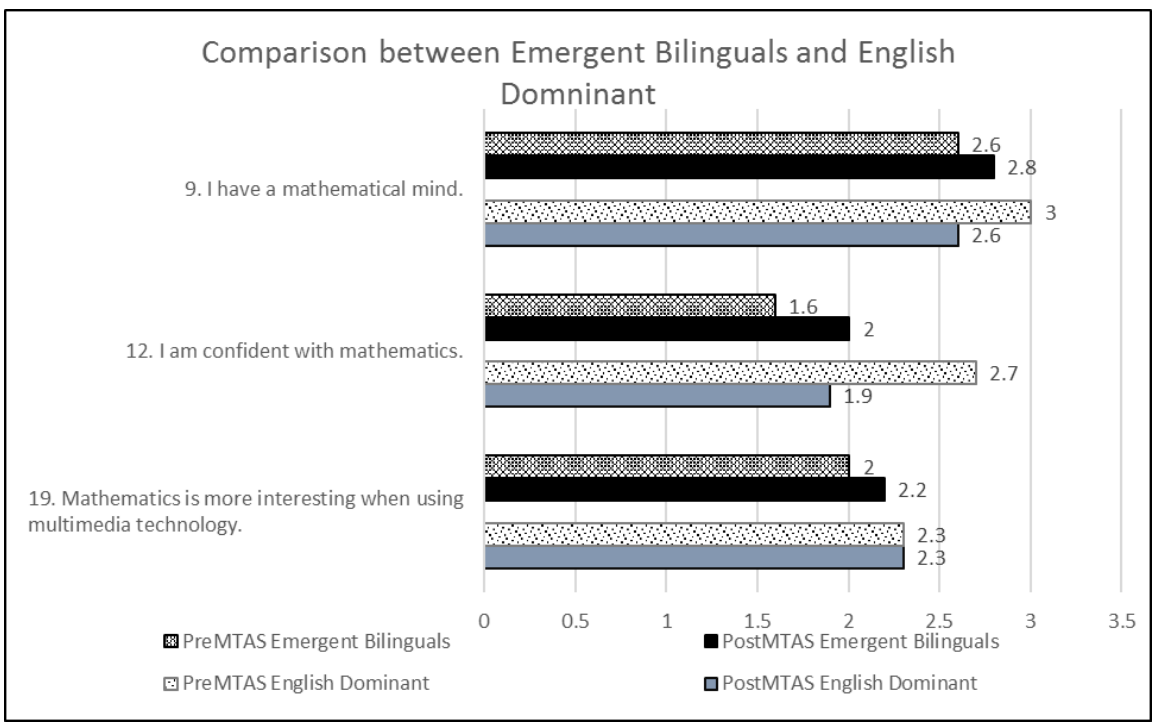

Figure 3. Bar graph showing emergent bilinguals increase in self-efficacy vs English-dominant participants' decrease or stagnation in self-efficacy.

Scholarly Significance

These findings contribute to the literature on emergent bilinguals' in several ways. The digital practices of emergent bilinguals' proved to be a complex sociocultural endeavour which they created and mediated. Translating software into an emergent bilinguals' native language allowed for participants' agency in creating an equitable learning environment. Utilizing software translation capabilities and online translators gave emergent bilinguals an opportunity to make meaning of English lexicon and mathematical syntax. Researchers and practitioners of online mathematics courses may find that allowing students, in particular, emergent bilinguals, to mediate translation utilities may create a bilingual digital mathematics course in which emergent bilinguals can acquire academic mathematical literacy.

Discussions

These findings contribute to the literature on emergent bilinguals' in several ways. The digital practices of emergent bilinguals' proved to be a complex sociocultural endeavour which they created and mediated. Translating software into an emergent bilinguals' native language allowed for participants' agency in creating an equitable learning environment. Utilizing software translation capabilities and online translators gave emergent bilinguals an opportunity to make meaning of English lexicon and mathematical syntax. Researchers and practitioners of online mathematics courses may find that allowing students, in particular, emergent bilinguals, to mediate translation utilities may create a bilingual digital mathematics course in which emergent bilinguals can acquire academic mathematical literacy. As we mentioned in the beginning of this paper, geometric explanations of mathematics-based pedagogical recommendations are usually more convincing than the usual algebraic ones, and the move convincing the explanations, the more willingly the teachers will follow them.

Conclusion

From the qualitative findings, four common themes emerged from the inductive analysis of the qualitative data involving course forum questions and email interviews with emergent bilinguals who had completed the demographic survey and responded to course forum questions. These four themes were the importance of learning English, translating software to Spanish and using online translators, meaning making, and students creating a bilingual digital learning environment.

These findings are significant because research on emergent bilinguals' digital practices and engagement with online mathematical courses has been largely unexplored. The findings of the qualitative data

revealed that emergent bilinguals' utilized digital practices to make meaning of English vocabulary and mathematical terminology. The results also revealed that emergent bilinguals made cognitive connections with mathematics by integrating their meaning making digital practices with culturally relevant videos and tutorials. For several emergent bilinguals, their digital practices increased the time on ALEKS to attain their final grade, however, on average, emergent bilinguals showed a higher percent increase from the ALEKS initial to final assessments. The results also indicated that emergent bilinguals did, in fact, increase their self-efficacy when translating the ALEKS software into Spanish. Integrating these two methods revealed emergent bilinguals' agency in developing mathematical biliteracy.

The findings in this study show a need for improvements on pedagogical and content in online mathematics courses:

1. Creating bilingual digital educational spaces.
2. Creating equitable digital spaces for emergent bilinguals and transnational students.
3. Developing applet resources in both English and Spanish to incorporate mathematical syntax, content misconceptions, and language misunderstandings.

References

ALEKS (2016). Math for Colleges and Universities, General Information, http://www.highedmath.aleks.com/about/Welcome-ENGLISH.html

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological review*, 84(2), 191-215.

Blunden, A. (2010). *An interdisciplinary theory of activity*, (Vol. 22). Boston, MA: Brill.

Canfield, W. (2001). ALEKS: A Web-based intelligent tutoring system. *Mathematics and Computer Education*, 35(2), 152-158.

Creswell, J. W., & Clark, V. L. P. (2007). *Designing and conducting mixed methods research*. Thousand Oaks, CA: SAGE Publications, Inc.

Di Martino, P., & Zan, R. (2010). 'Me and maths': towards a definition of attitude grounded on students' narratives. *Journal of mathematics teacher education*, 13(1), 27-48.

Engelbrecht, J., & Harding, A. (2005). Teaching undergraduate mathematics on the internet. *Educational studies in mathematics, 58*(2), 253-276.

Engeström, Y., Miettinen, R., & Punamäki, R. L. (1999). *Perspectives on activity theory*. New York, NY: Cambridge University Press.

Engeström, Y. (2001). Expansive learning at work: Toward an activity theoretical reconceptualization. *Journal of education and work*, 14(1), 133-156.

Esquinca, A. (2011). Bilingual college writers' collaborative writing of word problems. *Linguistics and Education*, 22(2), 150-167.

Falmagne, J., Doignon, J., P., Koppen, M., Villano, M., Johannesen, L. (1990). Introduction to knowledge spaces: How to build, test, and search them. *Psychological Review, 97*(2), 201-24.

Fine, A., Duggan, M., & Braddy, L. (2009). Removing remediation requirements: effectiveness of intervention programs. *Primus, 19*(5), 433-446.

Freeman, B. (2012). Using digital technologies to redress inequities for English language learners in the English speaking mathematics classroom. *Computers & Education*, 59(1), 50-62.

Griffiths, D., Heppell, S., Millwood, R., & Mladenova, G. (1994). Translating software: What it means and what it costs for small cultures and large cultures. *Computers & Education*, 22(1), 9-17.

Goldberg, H. R, & McKhann G. M. (2000). Student test scores are improved in a virtual learning environment. *Advances in Physiology Education, 23*, 59–66.

Hagerty, G., & Smith, S. S. (2005). Using the web-based interactive software ALEKS to enhance college algebra. *Mathematics and Computer Education*, *39*(3), 183-194.

Hagerty, G., Smith, S., & Goodwin, D. (2010). Redesigning college algebra: Combining educational theory and web-based learning to improve student attitudes and performance. *Primus, 20*(5), 418-437.

Hampikian, J., Guarino, J., Chyung, S.Y., Gardner,J., Moll, A., Pyke, P., and Schrader, C. (2006). Integrating pre-freshman engineering and precalculus mathematics. In R. Montgomery (Ed.). *Proceedings in American Society for Engineering Education*, 2006. Chicago, Illinois: ASEE.

Hampikian, J. Guarino, J., Chyung, S.Y., Gardner,J., Moll, A., Pyke, P., and Schrader, C. (2007). Benefits of a tutorial mathematics program for engineering students enrolled in precalculus: A template for assessment. In D. N. Buechler (Ed.). *Proceedings in American Society for Engineering Education Annual Conference & Exposition (pp. 24-27).* Honolulu, HI: ASEE

Harasim, L. (2012). *Learning theory and online technology*. New York, NY: Routledge.

Kitsantas, A., Cheema, J., & Ware, H. W. (2011). Mathematics achievement: The role of homework and self-efficacy beliefs. *Journal of Advanced Academics*, 22(2), 310-339.

Krogstad,J.M.(2016, July 28). 5 facts about Latinos and education.

Retrieved from http://www.pewresearch.org/fact-tank/2016/07/28/5-facts-about-latinos-and-education/

Lantolf, J. P., Thorne, S. L., & Poehner, M. E. (2015). Sociocultural theory and second language development. In B. VanPatten & J. Williams (Eds.), *Theories in second language acquisition: An introduction*, (pp. 207-226). New York, NY; Routledge.

Leont'ev, A. N. (1978). *Activity, consciousness, and personality*. Englewood Cliffs, CA: Prentice-Hall.

Luke, C. (2005). New literacies-new media: Mediascapes and infoscapes. *Pacific Archive of Digital Data for Education and Learning*, 1-19.

McClendon, M., & McArdle, M. (2002). Comparing alternative algebraic modalities for remedial students. Paper presented at the Chair Academy Leadership Conference, Kansas City, MO. Retrieved from http://files.eric.ed.gov/fulltext/ED464658.pdf

Moschkovich, J. (1999). Supporting the participation of English language learners in mathematical discussions. *For the learning of mathematics*, 19(1), 11-19.

Moschkovich, J. (2007). Using two languages when learning mathematics. *Educational Studies in Mathematics*, 64(2), 121-144.

Moschkovich, J. (2010). *Language and mathematics education: Multiple perspectives and directions for research*. Charlotte, NC: Information Age Publishing.

Muilenburg, L. Y., & Berge, Z. L. (2005). Student barriers to online learning: A factor analytic study. *Distance education*, 26(1), 29-48.

Reed, H. C., Drijvers, P., & Kirschner, P. A., (2010). Effects of attitudes and behaviors on learning mathematics with computer tools. *Computers & Education*, 55(1), 1-15.

Remillard, J. T., & Cahnmann, M. (2005). Researching mathematics teaching in bilingual bicultural classrooms. In T. L. McCarty (Ed.), *Language, literacy, and power in schooling*, (169-187). Mahwah, NJ: Lawrence Erlbaum Associates.

Rivera, H. H., & Waxman, H. C., (2011). Resilient and nonresilient Hispanic English language learners' attitudes toward their classroom learning environment in mathematics. *Journal of Education for Students Placed at Risk (JESPAR)*, 16(3), 185-200.

Spence, D. J., & Usher, E. L. (2007). Engagement with mathematics courseware in traditional and online remedial learning environments: Relationship to self-efficacy and achievement. *Journal of Educational Computing Research*, 37(3), 267-288.

Spradlin, K. (2011). The effectiveness of computer-assisted instruction in developmental mathematics. *Journal of Developmental Education*, *34*(2), 12-42.

Tahar, N. F., Ismail, Z., Zamani, N. D., & Adnan, N., (2010). Students' attitude toward mathematics: The use of factor analysis in determining the criteria. *Procedia-Social and Behavioral Sciences*, 8, 476-481.

Taylor, J. M. (2008). The effects of a computerized-algebra program on mathematics achievement of college and university freshmen enrolled in a developmental mathematics course. *Journal Of College Reading And Learning*, *39*(1), 35-53.

Vygotsky, L. S., (1960). *Development of the Higher Mental Functions.* Moscow, Russia: Publishing House of the R.S.F.S.R. Academy of Pedagogical Sciences.

Vygotsky, L., S., Hanfmann, E., & Vakar, G. (1986). *Thought and language*. Cambridge, MA: MIT press, (original work published 1934).

Vygotsky, L., S., (1979). Tool and symbol in child development. In M. Cole, V. John-Steiner, S. Scribner, & E. Souberman (Eds.). *Mind in Society: The development of higher psychological processes*. Cambridge, Mass: Harvard University Press.

Vygotsky, L., Hanfmann, E., & Vakar, G. (2012). *Thought and language*. Cambridge, MA: MIT press.

Yamagata-Lynch, L. C. (2010). *Activity systems analysis methods: Understanding complex learning environments*. Boston, MA: Springer.

Xu, Y., Meyer, K. A., & Morgan, D. D. (2009). A mixed-methods assessment of using an online commercial tutoring system to teach introductory statistics. *Journal Of Statistics Education, 17*(2).