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Emergent Bilinguals' Engagement In An Online Mathematics Course Utilizing An Intelligent Tutoring System

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EMERGENT BILINGUALS' ENGAGEMENT IN AN ONLINE MATHEMATICS COURSE UTILIZING AN INTELLIGENT TUTORING SYSTEM

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EMERGENT BILINGUALS' ENGAGEMENT IN AN ONLINE MATHEMATICS COURSE UTILIZING AN INTELLIGENT TUTORING SYSTEM

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Abstract

Students in today's digital world draw from multiple sources of information, hypertext, videos, educational software, social media, and video games to create a multimodal learning environment (Luke, 2005). In 1994, Griffiths, et al. (1994) found that the impact of information technology on oppressed cultures hampered their education when the technology was not available in their native language and culture. Students from countries that did not have the resources to develop software in their native language felt that their language and culture did not relate to the modern world. When these students arrived in the United States and found technology in English, they felt their native language was of lesser importance. Emergent bilinguals feel that educational software belongs to another culture and does not allow them to be agents in their learning. However, when they see their language embedded in the software, they engage with the software significantly more (Griffiths, 1994).

Gilster (1997) defined digital literacy as "the ability to access networked computer resources and use them" (p. xii). In more recent studies digital literacy has been defined as the practice of communicating, linking, and being involved in creating new ways of mixing multimedia tools to accomplish meaning making (Jones & Hafner, 2012). Emergent bilinguals mediate the use of online translators and the translating capabilities of an intelligent tutoring system for meaning making of the English register they encounter with the software. They search for culturally relevant videos and tutorial to create a cognitive connection between the mathematical topics and their native language.

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, two self-efficacy surveys, and email as well as face-to-face interviews, was analyzed 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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Chapter 1

Introduction

Overview

As digital technology and its myriad uses continue to evolve, it is important to understand the role it plays in socio-educational contexts. Luke (2005) found that in a technology-driven world, learners draw from a wide variety of sources to create a multimodal learning environment, digital practices and activities that utilize their language skills as an asset. These sources can include things like text, video, educational software, social media, and other digital technologies. Griffiths, Heppell, Millwood, and Mladenova (1994) found that the impact of information technology on oppressed cultures hampered their education when the technology was not available in their native language and culture. Students from countries that did not have the resources to develop software in their native language felt that their language and culture did not relate to the modern world. When these students arrived in the United States and found technology in English, they felt their native language was of lesser importance.

García, Kleifgen, and Falchi, (2008) define emergent bilinguals as students who are not yet proficient in English but are acquiring English through school to become bilinguals. There is a large variety in the population of emergent bilinguals in age, previous schooling and socio-economic status (Bruno, 2016). These researchers argue that using other terms to label this population of students (e.g., limited English proficient, language minority) perpetuates inequalities emergent bilinguals encounter in their education and ignore native language and cultural understanding. Vygotsky argues “language serves to mediate higher order thinking” (Vygotsky, 1960, 1979, 1986) challenging the role of language in the teaching-learning process. Bilingualism and biliteracy are assets (Escamilla & Hopewell, 2010; Moschkovich, 2015) that

need to be acknowledged by educators and researchers to create equitable educational environments.

The focus of this study is to explicate students meaning making strategies in creating equitable and bilingual digital learning environments. Consequently, the term emergent bilinguals is used as a description of participants language proficiency for this study as they become English proficient online math students but, more importantly, into successful bilingual mathematics students.

Emergent bilinguals in the United States find a dichotomy in their linguistic lives, using English for academics and technology and their native language at home and in social milieus (Griffiths et al. 1994). Although emergent bilinguals enjoy when they have the opportunity to utilize both English and their native language in school, they feel that they must learn proper language skills in an educational environment; this is known as the "standard language ideology" (Babino & Stewart, 2016; Milroy & Milroy, 1985). Thus, translating educational software into a student's native language could be very beneficial for emergent bilingual students who already participate in texting, online chatting, and searching the web in their native language (Casas, Goodman, & Pelaez, 2012; de la Piedra & Araujo, 2012; Wang & Liao, 2011). Care, however, must be taken when translating software that utilizes mathematical terminology.

Researchers have studied the linguistic challenges that emergent bilinguals encounter in learning mathematics in both English and Spanish (Gutierrez, 2002; Moschkovich, 2007, 2015; Remillard & Cahnmann, 2005). Confusion and tensions arise when emergent bilinguals encounter differences between English and Spanish mathematical syntax and terminology (Remillard & Cahnmann, 2005). For example, in English, the word "*menos*" may have two translations, less than or subtraction. The Spanish statements, "*cinco menos tres," and* "*tres*

menos que cinco" dually connote two distinct translations, respectively: "five minus three and three less than five," hence leading to an ambiguity of the word "*menos.*" Students not only have to search for a translation of a word or phrase, but they must find the mathematical context in which it was written. Educational software designers must be aware of the intended usages of mathematical vocabulary in order to provide an equitable environment for emergent bilinguals (Gutierrez, 2002; Remillard & Cahnmann 2005).

For this dissertation I utilized a mixed methods design, through an embedded-exploratory approach (Creswell & Clark, 2007), to examine how emergent bilinguals exploited the translating capabilities of an intelligent tutoring system and online translators to make meaning of an online pre-calculus course and how these meaning making activities affected their self-efficacy. This study was conducted in an online pre-calculus course over four semesters, from 2014 through 2016. Through an Activity Theory framework, I employed an embedded-exploratory design to analyze qualitative data supported by quantitative data.

Analyzing the multilayered qualitative data collection through the lens of Activity Theory, illuminated the complex relationships participants created between the mathematical content, their academic language proficiency, and sociocultural online environments. While making cognitive connections between prior knowledge acquired in their native language and new topics learned in English, participants' feelings about the importance of learning mathematics in English gave rise to internal tensions.

Quantitative data from Time-on-Topic and Learning-Progress Reports was analyzed to support participants' engagement and progress with the intelligent tutoring software. A pre- and post-survey on self-efficacy utilizing Bandura's (1977) Self-efficacy Theory were administered to participants taking pre-calculus in the 2016 spring and fall semesters. The self-efficacy data

was analyzed for an association between students' utilization of the software's translating capabilities for meaning making of mathematical terms, English vocabulary, and mathematics and technology.

Translating a Cognitive Tutor

An assemblage of Latin American and Caribbean (LAC) universities collaborated with Carnegie Mellon University to develop a cognitive tutoring system for primary and secondary mathematics classes (Casas et al., 2011). The participating universities were Pontificia Universidad Católica de Chile (PUC), Escuela Superior Politécnica del Litoral de Ecuador (ESPOL) and Tecnológico de Monterrey, México. A Math Cognitive Tutor (MCT) was developed and translated into Spanish by Carnegie Mellon University for these LAC universities to study if translating an MCT had a positive impact on improving students' mathematical skills (Casas et al., 2011). A math cognitive tutoring system is a software that allows students to progress through mathematical topics by scaffolding and practice using a constructivist approach for mastery-based learning. The MCT developed for this study was implemented in Algebra courses in secondary schools throughout the LAC countries.

Through a multivariate analysis of pre- and post-tests, this study found that students showed a statistical improvement in mathematical scores as well as improved scores on a national standardized mathematics test in Chile. The authors further discovered that 78% of the experimental students were satisfied with their math score improvement, while sixty-seven percent of the participants increased their motivation to do the math. Through qualitative analysis of self-efficacy surveys, the researchers observed that participant's positive attitudes towards math appeared to be correlated to having the cognitive tutor in their native language. This resource led participants to feel more confident in their abilities to solve complex

mathematics problems. Eighty-two percent of participants said they would like to use a similar program for other subjects, such as science classes. Finally, 88% of participants wanted to continue using computers in their Algebra classes. The researchers felt that these preliminary results indicated that learning mathematics could be positively impacted by technology translated into a student's native languages (Casas et al., 2012).

Emergent Bilinguals and Technology

Griffiths et al. (1994) observed that emergent bilingual students who used software written in English had a passive relationship with the computer and software. These students felt that their language and culture were not supported by the software and hindered their technological agency. Emergent bilinguals' self-efficacy could be negatively affected when they viewed their native language and culture as having less importance with technology. However, when emergent bilinguals encountered their native language embedded in the software, their engagement with the software significantly increased possibly increasing their self-efficacy as well (Griffiths et al., 1994).

According to sociocultural theorist, Lev Vygotsky (1962), subjects (students) learn through the use of mediated artifacts, discourse, and social interaction. In an online environment, this could be accomplished through digital discourse in the form of emails, course forums, texting, webinars, and blogs (Harasim, 2012). DeVillar and Faltis (1991) viewed software that encouraged communication, integrations, and cooperation as an asset for learning. Griffiths et al. (1994) opined that adaptation of software for non-English cultures could be beneficial in encouraging emergent bilinguals' communication and discourse. These researchers felt that software written in Spanish could benefit Spanish-English emergent bilingual students socially, educationally and economically. This is important as researchers have established that education

affords Latin@s with greater opportunities for social advancement and financial gain (Bates, 1997; Keister, Vallejo, & Borelli, 2013; Vallejo, 2009). Therefore, mathematical software translated into a student's native language could be a valuable tool for disadvantaged students to improve their educational and social status.

An intelligent tutoring system called ALEKS, (an acronym for **A**ssessment and **LE**arning in **K**nowledge **S**paces), introduced fully bilingual English-Spanish math products in June 2008 (ALEKS, 2016). ALEKS is the intelligent tutoring system utilized in the online pre-calculus course that was the focus of this study. An intelligent tutoring system is a mastery-based tutoring system that utilizes techniques from artificial intelligence to scaffold learning. Students enrolled in a math ALEKS course follow unique learning paths developed by the program and construct knowledge through practice problems and formative assessments. Researchers have opined that intelligent tutoring systems can be adapted to create an optimal English as a Second Language (ESL) environment (Casas et al. 2012; and Wang & Liao, 2011).

According to Harasim (2012) and Vygotsky (1960, 1986), learning takes place when learners solve problems beyond their actual developmental level via guidance by a teacher, peer or tool. Tools, such as computers and the internet, are utilized as experts by students to mediate their understanding of what they are learning (Leont'ev, 1978; Liu, 2014). Intelligent tutoring systems like ALEKS create knowledge spaces, or "zones of proximal development," where the software scaffolds the construction of knowledge for the learner. Sarmiento and Shumar (2010) argued that locating a student's knowledge space in a computer-supported collaborative learning environment positions students within the content of their zone of proximal development as competent members of an online culture. An intelligent tutoring system for emergent bilingual students may be beneficial to students' digital activities and practices within online math courses,

as well as to the instructors and developers of these classes. In sum, an intelligent tutoring system can potentially improve the ease and efficacy of encouraging students' mathematical literacy.

Cultural-Historical Activity Theory: CHAT

Socioculturalists, 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). Vygotsky isolated two interrelated features utilized in human activity; the tools mediated in each human activity and how people incorporated this activity into a system of relationships with others (Leont'ev, 1978). One such human activity that Vygotsky investigated was the acquisition of language through social interaction with experts and activity. Vygotsky called the true motive for an activity the object, which is what distinguished one activity from another; in this experiment, the motive (object) was the acquisition of language for humans (Leont'ev, 1978).

Leont'ev, Vygotsky's colleague, and student proposed that the object transforms the activity of the learner and does not exist without the learners' reflection as an activity (Leont'ev, 1978). Leont'ev contributed to Vygotsky's Activity Theory by placing the activity as the unit of analysis. Yrjö Engeström and Michael Cole 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). For the present study, content analysis of forum posts, email interviews and transcribed interviews were utilized to understand participants' digital practices through the lens of Activity Theory.

Problem Statement

Understanding the role of mathematics and applying mathematical skills in society aids emergent bilinguals in developing academic mathematical literacy. Mathematical literacy

emphasizes the development and application of problem-solving and higher-order thinking (Niss & Jablonka, 2014). Technology and globalization of information consumption and production require traditional definitions of literacies to be socially constructed and practiced digitally and in social networks (Gillen, 2014; Luke, 2005). However, emergent bilinguals' engagement in fully online mathematics courses has yet to be studied.

Existing literature does nonetheless provide valuable examples of how complex and diverse theories have been applied to the design of second language (L2) studies and the interpretation of data. Such studies have typically investigated *translanguaging*, best practices, mathematical academic literacies, and literacy in teaching mathematics for emergent bilinguals (Esquinca, 2011; Moschkovich, 2007, 2010, 2015; Remillard, & Cahnmann, 2005). Research literature on emergent bilinguals' self-efficacy and learning attitudes was correspondingly varied in both theory and depth (Canfield, 2001; Di Martino, & Zan, 2010; Freeman, 2012; Muilenburg & Berge, 2005; Reed, Drijvers, & Kirschner, 2010; Rivera, & Waxman, 2011; Spence, & Usher, 2007; Tahar, Ismail, Zamani, & Adnan, 2010). Yet, within this body of literature, there remains a paucity research looking at how emergent bilinguals engage with technology in mathematics classes and how this affects their self-efficacy in learning mathematics. Moreover, few scholars have focused on emergent bilinguals learning mathematics in an online environment and fewer still have researched emergent bilinguals' digital practices and self-efficacy in online mathematics courses.

As more and more college level mathematics courses are offered online, emergent bilinguals find themselves in a linguistic dilemma. They feel that the technology belongs to another culture and that their native language is of lesser values (Griffiths et al., 1994). Griffiths et al. (1994) further found that emergent bilinguals engaged with technology more when they

found their native language embedded in the software. A case study by Casas, Goodman, and Pelaez (2012) studied a cognitive tutor that was translated into Spanish for use in secondary mathematics courses in Latin American universities. These researchers found that participants improved their mathematical comprehension as well as had positive attitudes towards the technology. These studies indicate a need to continue research with emergent bilinguals in providing technology in participants' native language.

Understanding the role of mathematics and applying mathematical skills in society enables emergent bilinguals in developing academic mathematical literacy. Mathematical literacy emphasizes the development and application of problem-solving and higher order thinking (Jablonka, 2003). Technology and globalization of information consumption and production require traditional definitions of literacies to be socially constructed and practiced digitally, in social networks (Gillen, 2014); Luke, 2005). Emergent bilinguals' engagement in fully online mathematics courses has yet to be studied.

In addition, none of the aforementioned studies on emergent bilinguals' self-efficacy and learning attitudes employed Cultural Activity Theory; rather, they relied on quantitative methods to determine effectiveness and self-efficacy and/or ethnographic qualitative methods to discover students' attitudes towards math and technology (Canfield, 2001; Di Martino & Zan, 2010; Freeman, 2012; Muilenburg & Berge, 2005; Reed, Drijvers, & Kirschner, 2010; Rivera, & Waxman, 2011; Spence & Usher, 2007; Tahar, Ismail, Zamani, & Adnan, 2010). For this reason, this dissertation utilized Activity Theory to analyze participants' digital activity systems developed while engaged in an online pre-calculus course. Activity theory provided an innovative graphic model to explicate the essence of the complex data provided by the emergent

bilingual participants. This mixed methods study focused on how emergent bilinguals utilized digital activity systems to participate in an online pre-calculus course.

Research Questions

This mixed methods study was designed to explore how emergent bilinguals 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 qualitative research questions are:

1. How do undergraduate emergent bilinguals 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?

The quantitative research question is:

2. Do digital meaning making practices such as email, course forums, texting, translating software, and online videos impact self-efficacy?

Purpose of the Study

The purpose of this mixed methods study was to uncover emergent bilinguals' digital practices and experiences in an online college level mathematics course at the University of Texas at El Paso through an embedded-exploratory design (Creswell & Clark, 2011). Learning mathematical content, while learning a new language simultaneously, is a substantial challenge for emergent bilinguals (Crawford, 2013; Ganesh & Middleton, 2006). Emergent bilinguals must distinguish between informal English and academic mathematics register to infer the meaning of

instructions and/or explanations found in textbooks (Cuevas, 1984; Moschkovich, 1999, 2007; Planas & Setati, 2009).

Researchers have deduced that codeswitching, the use of more than one language in a single episode of discourse (Heller, 1988), and allowing students to speak in their native language while engaged in learning mathematics improved their understanding of the course content and instruction (Moschkovich, 2007, 2010; Planas & Setati, 2009; Slavit & Ernst-Slavit, 2007). Emergent bilinguals construct innovative digital spaces for making meaning of mathematical vocabulary as well as an understanding of course content and instructions, thereby developing mathematical biliteracy. This study will shine a light on emergent bilingual digital practices for meaning making in a fully online mathematics course.

ALEKS. 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 or 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 is 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). This dissertation study will not only fill the lacuna in the research literature for an underrepresented population in online educational environments; it will develop a set of tools to study emergent bilinguals' digital strategies in online mathematics courses.

Background Context

Researchers (Casas et al., 2012; Griffiths et al., 1994; Gutierrez, Baquedano-Lopez, & Tejeda, 1999; Gutiérrez, Morales, & Martinez, 2009; Moschkovich, 2010, 2015; Planas & Setati,

2009; Slavit & Ernst-Slavit, 2007) have found that for emergent bilingual students, learning mathematical concepts improved when they were allowed to use their culture and native language. Moschkovich (2007, 2015) and Gutierrez et al., (2005) further expounded that emergent bilinguals communicate mathematically through conjectures, presenting explanations, and constructing arguments about mathematical objects and content to make a mathematical conclusion. Software such as ALEKS which can be translated into Spanish may be beneficial for emergent bilinguals' understanding of mathematical concepts (Casas et al. 2012; & Wang & Liao, 2011). Creating a cognitive understanding of mathematical concepts is the goal of all mathematics educators. Thus developers of online math courses can utilize intelligent tutoring systems which can be translated into a students' native language to create holistic equitable educational digital environments.

In today's digital world, mathematical literacy has become a multimodal experience. With the rapid evolution of technology, there is an increasing need for studies that show how emergent bilinguals use technology in academics. A case study by Casas, Goodman, and Pelaez (2012) found that translating a cognitive tutoring system into Spanish improved students' mathematical content knowledge and attitudes towards mathematics. This dissertation will contribute to the research discussion on how emergent bilinguals develop culturally relevant online communities, the tools they use to mediate their goals and objectives and how they utilize digital practices to engage in an online mathematics course when the online course is in a second language.

Theoretical Framework

This doctoral study has as its theoretical framework, Cultural-Historical Activity Theory (Cole & Engeström, 1993; Engeström, Miettinen, & Punamäki, 1999). Cultural-Historical

Activity Theory (CHAT) or simply Activity Theory has its origins in Lev Vygotsky's work with Sociocultural Theory (Vygotsky, 1960, 1979, 1986). Activity theory is a framework that integrates and enhances analysis of data through various theoretical frameworks to systematically analyze human learning in settings where "multiple individuals are involved in shared activities within a single or multi-organizational context" (Yamagata-Lynch, 2010b, p. vii) or complex learning environment.

Students' digital literacies, relating, communicating, and meaning making with digital media impacted their abilities to decode graphical, numerical, and mathematical problem solving using higher order mental thinking, mathematical literacies (Jablonka, 2003; National Council of Teachers of Mathematics, 2017; Siebert, & Draper, 2012). Activity Theory graphically and systematically explicates students digital and mathematical literacies while engaged in a fully online pre-calculus course that utilized an intelligent tutoring system, ALEKS.

ALEKS, based on a constructivist theory, utilizes formative assessments to accurately determine students' knowledge state or zone of proximal development (Falmagne, et al., 1990). The knowledge state identified by ALEKS for individual students represents the topics that have been mastered by the student as well as the topics he or she is ready to learn. Sarmiento and Shumar (2010) posit that locating a student's knowledge space in a computer-supported collaborative learning environment positions students within the content of their zone of proximal development as competent members of an online community. Vygotsky's zone of proximal development theory is connected to development higher mental functions, where creations of mental imagery of mathematical concepts is created, in an online learning environment (Vygotsky, 1960).

Activity Theory Origins. The origins of Activity Theory can be traced to the 19th-century German philosopher J. W. von Goethe who did not want to predict or control the behavior of a subject, but rather allow the subject to be free to act. Goethe's key concepts were *Gestalt*, *Urphanomne,* and *Bildung.* Dictionary.com defines *Gestalt* as "a configuration, pattern, or organized field having specific properties that cannot be derived from the summation of its component parts; a unified whole." It is the idea that a phenomenon is represented by a conception of the whole rather than from its parts (Blunden, 2010). *Urphanomne*, which translates into "phenomenon" from Google Translate, is the unit of analysis. Finally, *Bildung*, which Google Translate defines as education, is personal development through life-long preservation and assumptions of the existing culture (Blunden, 2010). G. W. F. Hegel took Goethe's concept of "formation of consciousness" (Blunden, 2010) and the unit of social consciousness, to develop his principals on subject-object. Hegel's idea that human life begins with the whole rather than the individual contributed to scientific psychology and led to Marx's concept of activity.

Karl Marx was the first cultural-historical philosopher to clarify the theoretical and methodological core concepts of activity (Engeström et al., 1999). For Marx, people enter into practical activity with objects in their world and act on them to recognize their objective properties. Activity is not merely a reaction to an object. It is a system that has structure with its own internal transitions and development. Human activity represents a system within the system of relationships in society. For Marx activity was equivalent to human consciousness (Leont'ev, 1978).

Cultural-Historical Activity Theory was originally formulated by the philosophical works of Vygotsky, Luria, and Leont'ev. According to Vygotsky, people internalize societal rules of

activities then externalize them to create new rules, thus humans determine themselves through the objects they create (Engeström et al., 1999). Vygotsky created an innovative activity model to describe subjects mediated actions with tools to create new cognitive tools, called the object, (Figure 1.1). The object transforms the activity of the subject and cannot exist without the subject's psychological reflection as an activity. In this model, subjects do not wait for their environment to initiate meaning making processes for them, they make meaning of their world through their interactions with their environment to create and modify their activities that

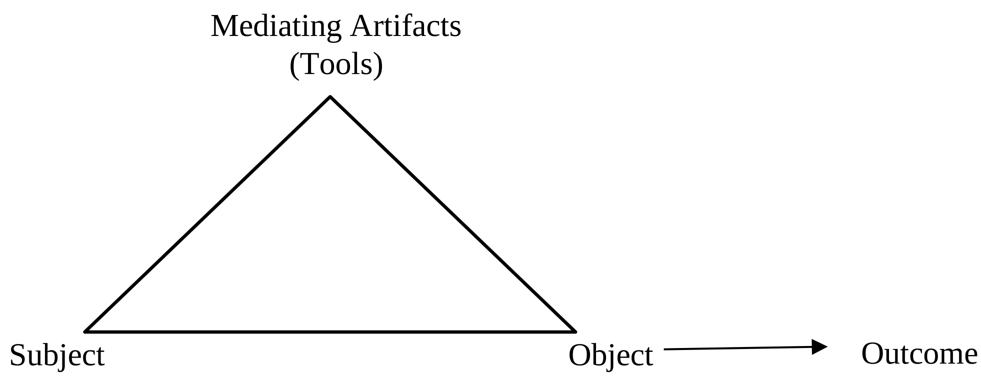


Figure 1.1. Vygotsky's activity system defining relationships between Subjects, Object, Mediating Artifacts and the Outcome of this activity System (Engeström et al., 1999)

transform artifacts, tools, and people in their social communities (Yamagata-Lynch, 2010a, 2010b). Leont'ev expanded Vygotsky model of mediated action by introducing human activity as the unit of analysis (Yamagata-Lynch, 2010b). Leont'ev developed a three level diagram of activity (Figure 1.2) in which activity is driven by the object-related motive (Engeström et al., 1999; Leont'ev, 1978). He further stipulated that action was driven by a goal and operation was driven by the conditions and tools of that action.

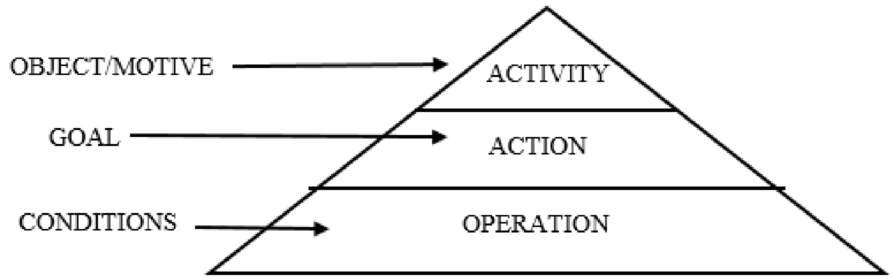


Figure 1.2. Leont'ev's activity system in which action is driven by a goal and operation is driven by the conditions and tools of action (adapted from Engeström et al., 1999).

Yrjö Engeström and Michael Cole developed the most recent generation of Activity Theory. Cole developed a theory in which a project is the unit of activity (Blunden, 2010; Cole & Engeström, 1993). He defined a project as something that is projected by the subject where the project is an on-going collection of actions (Blunden, 2010; Cole & Engeström, 1993). Engeström refined the activity system created by Vygotsky to show tensions as well as relationships between subject, mediated artifacts, and the object.

Engeström extended the activity triangular diagram from a micro-level concentration on the individual subject to a macro level to represent the social and collective elements in an activity system (Figure 1.3) (Blunden, 2010; Engeström, 2001). In this new model of Activity Theory, the upper triangle is equivalent to the triangle diagram developed by Vygotsky.

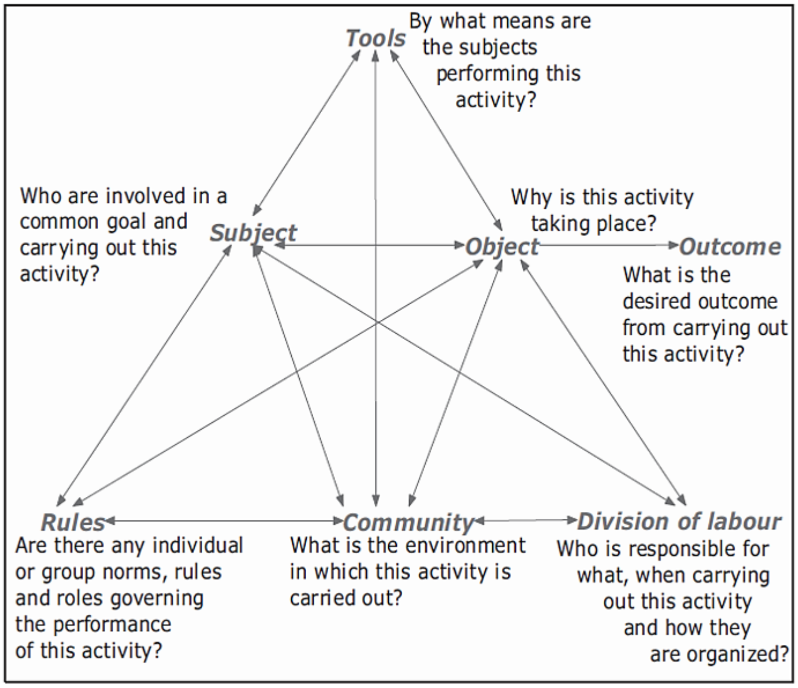


Figure 1.3. Engeström's expanded Activity Theory model (Zurita & Nussbaum, 2007).

In the lower half of the triangle diagram community, rules, and division of labor have been added to the activity system to emphasize the interactions between each component (Engeström, 2001). Each learner belongs to a community governed by rules that may be loose or rigid while engaging in an activity. The division of labor are the roles the learners play and the actions they undertake in an activity system (Blunden, 2010; Engeström et al., 1999; Yamagata-Lynch, 2010b).

According to Engeström (1987, 2001), outcomes are societally objectified meanings. The object is the motive which connects learners' actions to the activity. These object-oriented actions can be explicit or implicitly "characterized by ambiguity, surprise, interpretation, sense making, and potential for change" (Engeström, 2001, p.134). Engeström's revised Activity Theory emphasized how tension and contractions are at the core of human activity and are sources of change and development, or transformation (Engeström et al. 1999; Engeström,

2001). Engeström posits that these transformations should be investigated as to how they are resolved through practice and how they may be addressed in the future (Sannino, Daniels, & Gutiérrez, 2009).

The third generation of Activity Theory has emerged through the work of Engeström that conceptualized tools to understand dialogue, multiple perspectives, and networks of interacting activity systems (Figure 1.4) (Engeström, 2001). Gutiérrez et al. (1999) discussed the idea of boundary crossing through the concept of "third space" to account for new forms of meaning making through the discourse interactions of seemingly self-contained spaces of the teacher and students (Engeström, 2001). In these spaces, activity theorist see discourse interactions through a collaboration or boundary crossing of student and teacher actions that combine to form networks of activity systems.

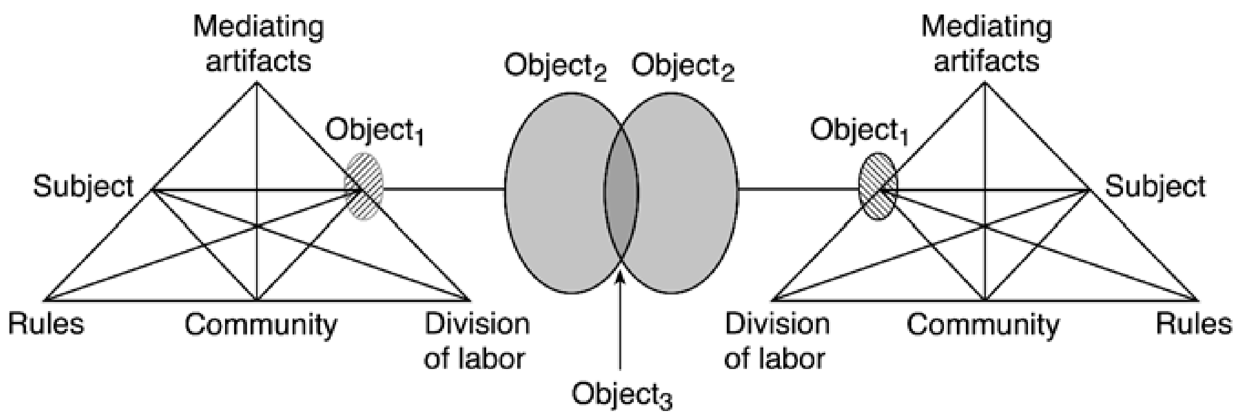


Figure 1.4. Two interacting activity systems as a minimal model for the third generation of Activity Theory (adapted from Engeström et al., 1999).

In this third generation activity model, the object (Object 1) of one activity systems moves to a collectively meaningful object (Object 2) constructed by the activity systems then melds into a jointly constructed object (Object 3) with the possibility of expansive

transformation. The study of an activity system and a network is a communal construction of its past, present and future zones of proximal development (Engeström et al., 1999 Engeström, 2001). Developing zones of proximal development is a key component of intelligent tutoring systems utilizing Knowledge Space Theory.

Knowledge Space Theory. Falmagne, et al. (1990) developed Knowledge Space Theory as a theory of how mathematical knowledge is constructed and how it can be described in a digital space. The formal field of artificial intelligence was initiated by Marvin Minsky, John McCarthy, Claude Shannon, and Nathan Rochester (Artificial Intelligence, 2016) in the 1950's; in the decades following its initiation, many AI applications have been developed. Adaptive Web-Based tutoring is the utilization of intelligent tutoring systems. An intelligent tutoring system, such as ALEKS, is a software program that utilizes Cognitive and Constructivist Learning Theories for mastery learning of course domain and has pedagogical strategies and cognitive tutoring capabilities. The constructivist nature of ALEKS can be associated with Vygotsky's Zone of Proximal Development, the distance between what an ALEKS user can achieve independently and what can be achieved through the scaffolding provided by the software (Crook, 1991; Vygotsky, 1986). Through Markovian procedures or conditional probabilities, ALEKS accurately and instantaneously determines the mathematical content a student has mastery of and creates an individual knowledge space for each student.

Digital literacies. Digital literacies have been referred to as the practice of relating, communicating, thinking and meaning making with digital media (Gillen, 2014: Gilster & Gilster, 1997; Jones & Hafner, 2012). The practices of internet searching, hypertextual navigation, and content evaluation are methods that can be applied to the future of the internet. They are not specific to hardware or software (Gilster & Gilster, 1997). A digitally literate

individual can search the internet efficiently and differentiates between relevant and irrelevant information (Bawden, 2008). They also multitask by mixing and matching digital tools to accomplish the goal at hand. Digital literacy theory is in its infancy and is still developing for meaning-making practices in education through ever changing technologies. The effect on how digital literacies affect student's self-efficacy in mathematics was studied in this research.

Self-efficacy. The central focus of self-efficacy theory is "the dynamic interplay among self-referent thought, action, and affect" (Bandura, 1986, p.124). Self-efficacy can be described as a person's opinion of their own capabilities in executing a course of action required to achieve a certain goal (Bandura, 1982, 1986; Pajares & Miller, 1995). Moschkovich (2007) found that language was an important aspect of positive attitude and self-efficacy for emergent bilingual students in a mathematics class. Self-efficacy can also be positively impacted for emergent bilinguals when they find technology in their native language and culture (Griffiths et al. 1994). These studies and more concluded that a student's self-efficacy correlated positively to their performance in mathematics classes (Casas et al. 2012; Freeman, 2012; Pajares & Miller, 1995; Rivera, & Waxman, 2011; Spence, & Usher, 2007; Tahar, Ismail, Zamani, & Adnan, 2010; Wang & Liao, 2011).

Research Design Overview

Utilizing Activity Theory allowed me to graphically and systematically explicate emerging bilinguals' digital practices while participating in a fully online pre-calculus course. Graphically modeling participants' activity systems organized complex data into a reliable interpretation from a real world setting that is a college course, in particular, an online mathematics course. In this embedded-exploratory design, innovative 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 access to the lived experiences and digital practices of emerging bilinguals participating in a fully online pre-calculus course over four semesters.

Funneling procedure. The participants for this study were recruited from an online pre-calculus class over four semesters at The University of Texas at El Paso, which is located on the U.S.-Mexico border. A recruitment email was sent to all students enrolled in this online pre-calculus course detailing their involvement in this study and a link to the demographic survey. Eight hundred and eighty-seven students enrolled in the four online pre-calculus course, of these students, three hundred and nine signed the consent form to participate in this study. Students who signed the digital consent and completed the demographic survey were identified as participants in this study.

Through the Cross Tabulation feature on Qualtrics, an association between the language used by participants in school and at home and how often they utilized online translators, think in Spanish while working on math problems, and how often they translated words in their mind while working on math problems was determined. Participants identified as Spanish-dominant emergent bilinguals through self-reporting on an initial demographic survey and English as a Second Language (ESL) classes taken at the university were amassed into a focus group. Through content analysis of course forum posts and demographic survey, Spanish-dominant emerging bilinguals were further funneled into a smaller focus group labeled Digital informants. Digital informants were those participants who provided data, digitally, through course forum posts and emails. Finally, those Digital informants who provided in-depth information to email interviews were further funneled into a group labeled Funneled informants. The Funneled informants participated in a face-to-face interview at the end of each semester.

Overview of data collection. Through qualitative and quantitative analysis, the participants in a fully online pre-calculus course participated in one demographic survey, two pre- and post- self-efficacy surveys, daily course forum questions, email interviews, face-to-face interviews and provided artifacts such as daily logs and screenshots of their online activities while working on ALEKS. Participants in this study responded to course forums questions, email and face-to-face interviews to provide qualitative data for analysis. Utilizing a two-way multivariate analysis of variance for pre- and post- self-efficacy surveys and using a 5-point Likert scale, degrees of association between translating the software and self-efficacy were determined to have no statistical interaction between the two. Analysis of the quantitative data occurred at the end of the 2016 spring and fall semesters, respectively.

The initial survey, with demographic and educational information, was completed by students who signed the digital consent forms within the first two weeks of each semester. Weekly forum questions were posted on the ALEKS, and participants responded to these course forum posts. Participants' responses were collected throughout the semester and analyzed through content analysis for codes and themes. Through constant comparative methods, the data from the surveys, forum posts and email interviews were analyzed and coded into themes. Key informants for email interviews and daily log submissions were identified from those participants who provided rich, in-depth information on their lived experiences in the course forum responses.

Participants in the 2016 spring and fall semesters completed two self-efficacy pre- and post-surveys, which measured their attitudes towards mathematics, everyday mathematical problems, and technology used for math classes, based on Self-Efficacy Theory developed by Albert Bandura (1977). The Mathematics and Technology Attitudes Scale (MTAS), developed

by Robyn Pierce, Kay Stacey, and Anastasios Barkatsas was comprised of twenty-seven items measuring confidence and attitudes with mathematics and technology on a 5-point Likert scale (Pierce, Stacey, & Barkatsas 2007). The Mathematics Self-Efficacy Survey (MSES) assessed a student's confidence in everyday mathematical tasks, math problems and math-based college courses (Betz & Hackett, 1983). The MSES survey contained thirty-four items measured on a 5-point Likert scale. The findings in this study allowed for the discovery of how emergent bilinguals utilized their digital practices to make meaning of mathematical concepts and how these digital practices were associated to their mathematical and technology self-efficacy.

Study Design. This study followed an embedded-exploratory design and utilized four phases for data collection and analysis (Creswell & Clark, 2007). In phase one, students were recruited via email to participant in this mixed methods study. Students who agreed to participate in this study followed a link provided in the email recruitment email to a digital consent form and demographic survey. In phase two, participants posted responses to course forum questions and completed two pre-self-efficacy surveys: 1) Mathematics and Technology Attitudes Scale and 2) Mathematics Self-Efficacy Survey. Constant content analyses of course forum posts and the demographic survey occurred throughout phase two.

In phase three, Digital informants were sent open-ended questions through email to explore further their forum posts and digital practices. Constant comparison and content analysis were conducted on the course forum posts and email interview through which new themes emerged and previous ones were confirmed. Daily logs were collected from participants depicting their digital activities while working on ALEKS. Participant submitted screen shots of their translation activities as well as their internet searches for meaning making. In phase three participants also completed two post-self-efficacy surveys, the MSES and the MTAS. In phase

four statistical analysis of the pre- and post-surveys were performed to find an association between emergent bilinguals' self-efficacy and translating the software into Spanish. Finally, the final analysis of all qualitative data was conducted, interpreted and integrated into the results of this study.

Assumptions. As a scholar, I assumed that the findings of this study would be based on my experience as a practitioner. I assumed that once translated emergent bilingual participants would not return to the English version of the software as a meaning making strategy. I further assumed that all emergent bilinguals regardless of their language proficiency level would use this strategy. Since I am a lifelong resident of this region and as an emergent bilingual as well, I assumed the participants' responses to course forum questions, email questions and interviews were provided openly and with all honesty. I further assumed that I asked the correct questions for each form of data collection.

Rationale and Significance

Software that can be adapted to create an optimal educational environment for emergent bilinguals is favored by several researchers (Casas et al. 2012; Moschkovich, 2007, 2010; Wang & Liao, 2011). Researchers like Moschkovich (2007, 2010) have posited that emergent bilinguals who use their language in formal and informal mathematical education benefit significantly. Students learn about mathematical situations, communicate about these situations and use vocabulary and digital resources for mathematizing and communication (Moschkovich, 2007).

Several natural questions for researchers of emergent bilinguals may be: How do emergent bilingual students utilize their native language and culture in an online environment? How do emergent bilinguals engage in a fully online mathematics course through the mediation

of an intelligent tutoring system and the internet? How do contradictions and tensions between L1 acquisition and mathematical knowledge in their native language reformulate their class activities? Practitioners and developers of online mathematics courses can benefit from understanding the digital practices of emergent bilinguals. They can create an online educational environment where students are encouraged to utilize translators and search for a culturally relevant tutorial. Developers of online mathematics courses can also search for educational software that can be translated into several languages as well as written with a multicultural perspective. Researchers of emergent bilinguals may use the ideas in this dissertation study for future studies.

Stance of the Researcher

Growing up with bilingual parents, stories were often related to my sister and me about their experiences while attending elementary school in a U.S-Mexican border town as emerging bilinguals. My father, for example, was not allowed to speak Spanish in the classroom, on the playground or in the hallways of the Catholic elementary school which he attended. If he was on school property, he and his friends were required to speak English. When he and his friends were caught speaking Spanish, the nuns would punish them, which he said would consist of hitting the backs of their hand with a ruler. In his eyes, Latinos were discriminated against in school, at their jobs, and in society even in a border city where a high percentage of the population consisted of Latinos. For this reason, he felt an education was of great importance and encouraged me to attain a college degree. He also felt that in order to be seen as a peer I had to work harder than my colleagues and perform at a higher level as well. Unfortunately, my father did not see bilingualism as an asset for my future.

It was in high school that I first encountered a teacher who described how being bilingual could be an asset. She emphasized that in the border region we could communicate to both Americans and Mexican nationals who participate in transnational commerce. It became apparent to me that knowing a second language was becoming a global trend and an asset with the advent of international collaboration with industry and the onset of the World Wide Web. However, I was unsure of how I could implement my bilingualism as an educator. Throughout my education, I learned mathematical terminology in English, but when I began my career as a teacher, I had to learn these terms in Spanish. When a student, who only spoke Spanish was placed into my classroom, I found that in order to communicate with her, I had to learn mathematical terminology in Spanish.

I have taught mathematics for over twenty years at the high school and collegiate level on the U.S.-Mexico border. Many of my students were emergent bilinguals, as I was at their age. Growing up in a household where English and Spanish were spoken but neither academically correct, I struggled to understand complex academic instructions in my math and science classes. When I became a teacher and as a native Spanish speaker, I allowed Spanish-English emergent bilingual students to converse with me in their native language in order to make meaning of mathematical content and vocabulary. I developed a mastery-based curriculum for my students because they entered my classroom at different levels of mathematical content knowledge. I continued developing a mastery-based curriculum when I was hired to coordinate the pre-calculus program at the university.

In the spring of 2010, I developed and taught an online pre-calculus class utilizing the intelligent tutoring system called ALEKS. I chose ALEKS, because it utilizes Constructivist Learning Theory for mastery-based learning and because it could easily be translated into

Spanish. My assumption was that emergent bilingual students in my online course would change the software into Spanish throughout the semester to understand the content. In March 2012, I was accepted into a doctoral program for Teaching Learning and Culture. As I progressed with my doctoral coursework, I observed that emergent bilinguals in the online pre-calculus class did not translate the software into Spanish throughout the semester as I had assumed. They regarded the online software as an opportunity to strengthen their English language proficiency. They utilized the internet and created online strategies to complete the required course work. As a doctoral student, searching the research literature for emergent bilinguals' behaviors and strategies for engaging in online mathematics courses proved unsuccessful. The research literature on emergent bilinguals focused on mathematical achievement, attitudes, and self-efficacy in face-to-face math classes. This doctoral study will analyze the lacuna in the literature on emergent bilinguals' engagement in an online mathematics course.

Definitions of Key Terminology

I define key terms operationally here so that readers will understand how they were used in the study.

Biliteracy: A continuum of acquiring literacy and bilingualism simultaneously in two or more languages, "in which communication occurs in two (or more) languages in or around writing," (see Appendix Q for more details) (Hornberger, 1995, p. 177).

Codeswitching: Codeswitching is the use of more than one language in a single episode of discourse (Heller, 1988).

Emergent bilinguals: English language learners who are acquiring the ability to continue to function in their native language as well as in English, their new language and academic language (García, & Kleifgen, 2010).

Knowledge Space Theory: A knowledge state is defined as a set of questions that a student is able of answering in ideal conditions. A knowledge space is a set of knowledge states for some student (Falmagne et al., 1990).

Math cognitive tutor: A software or online program designed to scaffold mathematical topics using a constructivist approach to creating a mastery-based learning environment (Harasim, 2012).

Meaning making: Meaning making is the construction of knowledge as a complex synthesis of interdependent processes into understanding inside the social relationship with others and across a variety of contexts and codes (Vygotsky, 1986).

Intelligent tutoring system: An intelligent tutoring system is a mastery-based tutoring system that utilizes techniques from artificial intelligence to create knowledge spaces or zones of proximal development where the software scaffolds the construction of knowledge for the learner (Harasim, 2012).

Summary of Chapter 1

Chapter 1 introduced digital practices in a fully online mathematics course through the lens of Activity Theory, a topic that has yet to be fully researched concerning emergent bilinguals, as the focus of study. The educational literature shows that emergent bilingual students can improve their mathematical literacy and increase their self-efficacy if allowed to utilize their culture and native language. The research literature further shows that mathematical software can be beneficial for emergent bilinguals if the software contains the capacity to be translated into their native language. Discovering how emergent bilinguals use language to create activity systems for meaning making of mathematical terms may help researchers understand emergent bilinguals' online practices while enrolled in an online mathematics course.

Overview of Dissertation

Chapter 2 will situate this study in the current literature for emergent bilinguals' digital practices and their active participation in online mathematics courses. Chapter 2 will begin with a discussion on early implementation of online mathematics courses and how emergent bilinguals are represented in the literature. A history of Activity Theory is explained through the development of sociocultural theory and the theorist, philosophers who developed it. A theoretical connection with Vygotsky's zone of proximal development and knowledge space theory will be discussed, followed by the development of an intelligent tutoring system, ALEKS through knowledge space theory. An overview of the effectiveness of ALEKS on students' performance on mathematics courses, college placement, and a standardized test will also be presented.

The remaining sections of Chapter 2 will focus on emergent bilinguals in mathematics courses. This discussion will begin with a case study on the translation of a cognitive math tutor which leads to the linguistic challenges emergent bilinguals face in developing biliteracy and academic mathematical literacy. Self-efficacy theory will be deliberated to situate emergent bilinguals' digital practices and learning attitudes in the current literature. Finally, implications of this study for practitioners and developers of online mathematics courses will be presented.

Chapter 3 will demonstrate the methodology which was utilized for this study to explicate the digital practices of emergent bilinguals in a fully online pre-calculus course. A mixed methods embedded-exploratory design was utilized to explore the experiences of emergent bilingual students in an online pre-calculus course over four semesters at the University of Texas at El Paso. The setting of the study, ethical considerations, design and innovative sampling procedures will be presented in this chapter. The four phase data collection

will also be described to ensure trustworthiness of this study. The timeline for this study is presented at the end of this chapter.

Chapter 4 delves into the context of the activity systems developed to describe and explicate the actions of emergent bilinguals to mediate their use of translations and culturally relevant videos to make meaning in this online mathematics course. The subjects for each activity system are identified and the rules that governed their activities in this class are also defined. Their motive, objects, for their activities will be developed as well as their final outcome, which was to make cognitive mathematical connections in both English and Spanish. The changing communities from each activity system will be developed and explained. Finally, the mediated artifacts, translating ALEKS, using online translators, and finding culturally relevant videos and tutorials will be explored through the tensions and contradictions emergent bilinguals encountered within their activities.

Chapter 5 will present the findings of this study. Chapter 5 opens by situating this study within the research literature for emerging bilinguals by stating the purpose of this study. The methodology and intelligent tutoring systems will be reviewed in the following sections. The funneling procedure utilized to identify key informants will be defined and presented in this chapter. Several funneled informants lived experiences will be presented to further support the findings. Each analysis phase will be described in great detail. The tensions identified through the analysis of the data will be described and connected to the research questions. All data analysis will be interpreted to complete the connections to the research questions.

Chapter 6 will close this study with a summary of the findings. A thorough discussion of the implications and limitations will be presented. Final recommendations for future research

will be presented in this chapter. The appendices present the documents that were relevant to this study.

Chapter 2

Literature Review

Overview

This chapter will present an overview of the literature pertaining to emergent bilinguals' digital practices while engaged in a fully online mathematics courses through an Activity Theory lens. Field-based research methodologies fundamental to ethnography is also central to Activity Theory. Ethnography and Activity Theory share the philosophy that behavior, i.e. activity, should be the unit of analysis; they also recognize that objects, i.e. artifacts, are crucial components in descriptive and explanatory accounts of human experience (Engeström et al., 1999). The opening sections of this chapter will provide a historical overview of online mathematics courses and a historical and theoretical depiction of Cultural-Historical Activity Theory (CHAT). The following sections provide a review of research literature on intelligent tutoring systems, Knowledge Space Theory, and mathematical literacies. The final section expounds on the literature about emergent bilinguals' self-efficacy and attitudes in traditional mathematical courses and the use of technology in mathematics courses. In this chapter, the literature review provides a comprehensive description of the theories constituting the theoretical framework guiding this study.

Online Math Courses

The design of online mathematics courses has progressed from simply uploading PowerPoint files onto a server mimicking lectures in a traditional face-to-face course, to the utilization of online intelligent tutoring systems (ITS) (Engelbrecht & Harding, 2005; Harasim, 2012). Technological advances such as high-bandwidth access and streaming media have enhanced online education through improved delivery of images, interactive textbooks, videos,

and mathematical animations. Educators have adopted new technologies in both formal and informal educational settings through "trial-and-error methods and by adapting traditional didactic practices to online environments" (Harasim, 2012, p. 3). These online environments are facilitated by the use of online learning systems.

Online learning systems, cognitive tutors and/or intelligent tutoring systems are computer programs that incorporate techniques from the field of Artificial Intelligence (AI) to provide a digital tutor with full mastery of the course content. A digital tutor provides diagnostic testing for constructing a student's zone of proximal development and develops scaffolded instruction for individual students (Stankov, 2010). Each student follows a learning path that has been diagnostically developed for them individually by the cognitive tutor based on their zone of proximal development. In the 1980's and 90's the development of these scaffolding computer-based learning systems (CBLS) created learning environments where students progressed within their own unique zones of proximal development (Borthick, Jones, & Wakai, 2003; Harasim, 2012; Vygotsky, 1960, 1986).

The intelligent tutoring system utilized in the fully online pre-calculus course for this study is called ALEKS, which is an acronym derived from "**A**ssessment and **LE**arning in **K**nowledge **S**paces.". One unique feature of ALEKS pertinent to this study is that the entire program can be translated into Spanish by clicking on a single drop down menu. At present, Spanish is the only language in which ALEKS has been translated and made publicly available to students. The simplicity of translating the software into Spanish was the catalyst for pursuing this mixed methods study on emergent bilinguals digital engagement in an online mathematics course taught at a university in the United States. Activity Theory, as adapted by Engeström et

al. (1999) was utilized to depict how emergent bilinguals mediate the translation capabilities of this intelligent tutoring system for meaning making of mathematical terminology.

Meaning making is the construction of knowledge as a complex synthesis of interdependent processes into understanding inside the social relationship with others and across a variety of contexts and codes (Vygotsky, 1986). While meaning making is often referred to as learning, comprehending, or understanding, it is processed through a learners' lived experiences or social situation of development, a learner's prism of perezhivanie (Connery, John-Steiner, & Marjanovic-Shane, 2010; Vygotsky, 1960, 1986). The development of learners in a technological world involves the discovery and synthesis of concrete and conceptual digital tools from past generations (Connery et al., 2010; Vygotsky, 1960, 1978). A cultural-historical approach for meaning making can be developed through Activity Theory.

Activity Theory

Cultural-Historical Activity Theory (abbreviated as "CHAT" or "Activity Theory") originated with German and Russian philosophers, drawing its name from both languages (Roth & Lee, 2007). *Aktivität*, the German word for "activity," means being busy, doing something, while in Russian the term for 'activity' is деятельность " (deyatel'nost'), which means societally motivated and society-sustaining human endeavors (Roth & Lee, 2007). Google Translate provides the following translations for деятельность: activity, action, performance, working and practice. Cultural-Historical Activity Theory provides a framework for understanding human activity (Engeström et al., 1999; Lantolf, Thorne, & Poehner, 2015; Kaptelinin & Nardi, 2012; Roth & Lee, 2007; Vygotsky, 1986; Yamagata-Lynch, 2010b). CHAT is the basis of the theoretical framework that guides this study.

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; Kaptelinin & Nardi, 2012; Roth & Lee, 2007; Yamagata-Lynch, 2010b). The activity in which the subject engages is additionally influenced by the rules which govern the social community in which the subject resides and by the tasks, or roles, of that community (Engeström et al., 1999; Kaptelinin & Nardi, 2012; Yamagata-Lynch, 2010b). This is consistent with ethnographic studies that focus on behavior and activity to describe and explain human experiences. What follows is a description of the predecessors and historical evolution of Activity Theory.

In the 19th-century, the German philosopher Goethe developed three key concepts for subject analyses that focused on the unrestricted actions of a subject, rather than on attempting to predict or control the behavior of a subject (Blunden, 2010; Cole & Engeström, 1993; Yamagata-Lynch, 2010b). The first concept was *Gestalt* ["*form*" according to Google Translate]. Gestalt is the idea that "the representation of a phenomenon must begin from a conception of the whole, rather than being assembled from the parts" (Blunden, 2010, p. 6). The second concept, *Urphänomen* ["*phenomenon"* according to Google Translate], "is 'the unit of analyses' of a complex phenomenon" (Blunden, 2010, p. 6), or the smallest, simplest example of the phenomenon. The third and final concept was *Bildung* ["*education"* according to Google Translate]: "a concept of personal development which understands the process of growth as life-long maintenance and appropriation of the existing culture." (Blunden, 2010, p. 6). These three concepts influenced philosophers on human consciousness in Germany and Russia.

Hegel was a German philosopher who is credited with the development of idealism ("Georg Wilhelm Friedrich Hegel," n.d.). He drew on the concept of *Gestalt* as a "formation of

consciousness" and the unit of social consciousness to develop his contributions to scientific psychology, idealism (Blunden, 2010; Yamagata-Lynch, 2010b). Hegel believed that human life begins with the whole, social consciousness, rather than the individual. He also believed that there were two distinct stages in human life: first, that human physiology is produced by a natural process; second, a cultural process which begins after birth (Blunden, 2010; Yamagata-Lynch, 2010b).

Moses Hess was considered a "Young Hegelian" who introduced Marx to Communism. Hess wrote the book "Philosophy of the Act" (*Philosophie der Tat*), where *tat* is a French root word meaning activity. Here Hess gave the idea of appropriating Hegel and using activity as the fundamental substance, a militant spin. According to Blunden (2010), "Marx used the notion of activity from Moses Hess to make a materialistic interpretation of Hegel's 'spirit'" (2010, p. 7).

Marx was the first cultural-historical philosopher to clarify the theoretical and methodological core concepts of activity in order to understand the interaction between humans and their environment in natural settings (Cole & Engeström, 1993; Engeström et al., 1999; Yamagata-Lynch, 2010b). For Marx, human life was rooted in social participation in practical activities; activities which people enter in with objects from their surrounding world, test the activities resistance and act on them to recognize their objective properties (Leont'ev, 1978; Sannino, Daniels, & Gutierrez, 2009). For these early cultural-historical philosophers, activity was a unit of life; it oriented the subject in the objective world (Leont'ev, 1978). Activity was a system that has structure, internal transitions, and transformations, its own development, and cannot be considered isolated from social relations (Leont'ev, 1978). Psychologists, Vygotsky, Rubinstein, Luria and Leont'ev further developed Activity Theory into its first generation (Kaptelinin & Nardi, 2012).

First generation Activity Theory. Cultural-Historical Activity Theory was developed by Vygotsky, Luria and Leont'ev (Cole & Engeström, 1993; Engeström et al., 1999; Lantolf, Thorne, & Poehner, 2015). They believed that human learning and behavior resulted from the mediation of cultural artifacts, activities, and concepts (Lantolf, Thorne, & Poehner, 2015; Kaptelinin & Nardi, 2012; Vygotsky, 1962; Yamagata-Lynch, 2010b). Vygotsky hypothesized that learners internalized the societal tools of activities, then externalized them to create new tools for the realization of a goal, i.e., the object (Engeström et al., 1999; Kaptelinin & Nardi, 2012; Liu, 2014). Vygotsky posited that learners have the ability to utilize a tool to perform a more difficult activity then they could do alone, and thus improve their cognitive skills and potentially internalize and determine themselves as a human through the object they have created (Engeström et al., 1999; Kaptelinin & Nardi, 2012; Liu, 2014). This internalization of an activity can be the basis for automaticity of mathematical concepts according to Cultural-Historical Activity Theory (Davydov & Andronov, 1981; Roth & Lee, 2007).

Vygotsky created a triangular diagram to represent the relationships between a subject, mediated artifacts or tools, and the object or motivation for the activity (Figure 2.1). The subject in Figure 2.1 is the learner performing an activity (Cole & Engeström, 1993; Engeström et al., 1999; Kaptelinin & Nardi, 2012). The object is the true motive of the activity (Leont'ev,

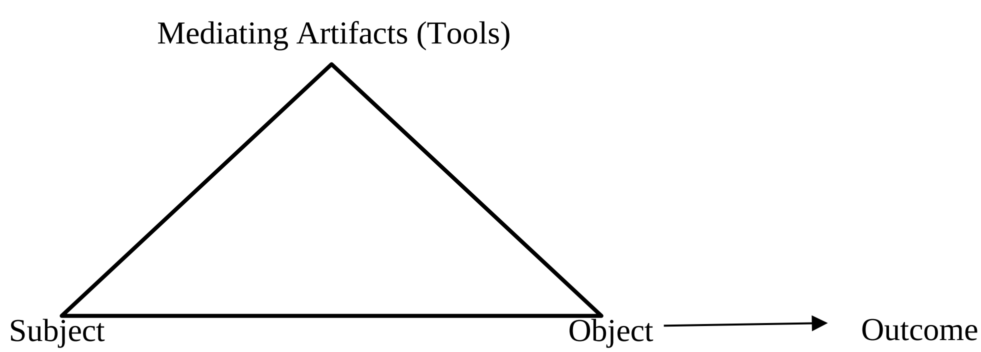


Figure 2.1. Vygotsky's mediated activity system (adapted from Engeström et al., 1999).

1978), e.g. making meaning of mathematical terminology by an emergent bilingual. A learner may perform the action of clicking on the translation button in ALEKS; however, the activity of mediating the translation is motivated by the desire to make meaning of the terminology.

Vygotsky claimed that higher order forms of mental functioning are mediated by cultural artifacts which can be external or internal (Fernyhough, 2008; Vygotsky, 1960, 1986). Mediation has been described by the behavioral sciences as a process where a cultural tool plays a causal role in the relationship between two entities, such as the subject and object of the triangle diagram (Fernyhough, 2008). A tool mediates human activity to become part of the cultural context of other learners, connecting learners with his/her physical surroundings but also to others (Leont'ev, 1978, Fernyhough, 2008). In an online environment, the separation between a tool and reality is vague.

Mediating artifacts and tools is a way of transmitting cultural knowledge (Kaptelini, 1996). Tools shape the objects and motives of learners who use them. Kaptelinin (1996) posited that from a cognitive approach Activity Theory considers technology as a specific type of tool mediating human interaction with the world. Learners utilized computers and technology to reach certain goals beyond that of a dialogue with the computer. Consequently, Bodker (1989) opined that use of technology must include the context of the learner's goals, environment, available tools, and interactions with other learners.

Mediating artifacts or tools can be external, such as computers and cognitive tutors, or they can be internal, such as language and mathematical prior knowledge. These tools are utilized by the learner to mediate the actions of the subject in order to reach the motive of the activity, the object. The activity systems final product is the outcome, for example, an emergent bilingual's mathematical comprehension.

Second generation Activity Theory. Vygotsky's student A. N. Leont'ev hypothesized that learners engage in goal-oriented actions; thus he focused the unit of analysis on the activity rather than on mediation of tools (Cole & Engeström, 1993; Engeström et al., 1999; Liu, 2014). For Leont'ev, human activity represented one system that is an integral portion of the overall system of relationships of society (Leont'ev, 1978). Leont'ev believed the object transforms the activity of the subject and cannot exist without reflection as an activity by the subject (Engeström et al., 1999; Lantolf, Thorne, & Poehner, 2015). Leont'ev described Vygotsky's triangular diagram for activity as a hierarchical system (Figure 2.2). The operations (in the ALEKS example, clicking on translation buttons) are driven by the conditions and tools that shape the action. The actions are driven by the goal (making meaning of mathematical terms) and thus shape the activity that is driven by an object-related motive (Engeström et al., 1999; Lantolf, Thorne, & Poehner, 2015; Liu, 2014; Leont'ev, 1978).

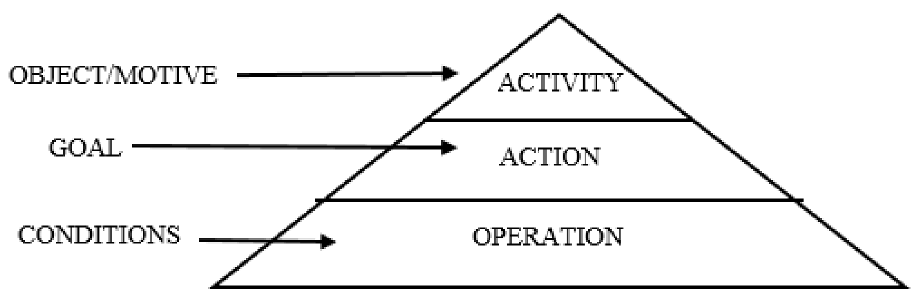


Figure 2.2. Leont'ev's hierarchical activity system (adapted from Engeström et al., 1999).

Two emergent bilinguals who click on the translation button of an intelligent tutoring system are performing an identical action, yet the motive of each student may be different. One student may be searching for meaning making of one or two mathematical terms, while the other may be struggling to understand the register of the language of instruction as a whole. This

example is an illustration of the key Activity Theory tenet that the object transforms the activity of the subject (Cole & Engeström, 1993; Engeström et al., 1999; Leont'ev, 1978). The mediation of the tools is influenced by the role of the learner and the social community that he/she belongs to. To this end, Engeström (1999) developed a second generation triangle diagram of an activity system (Figure 2.3).

Vygotsky's activity triangle of mediated action is represented in the upper portion of Engeström's triangle in Figure 2.3. The subject, object, and mediated tools have the same definitions as in the first generation activity system. The lower half of the triangle represents the social context of the activity system. The community in the diagram is the sociocultural environment in which the object of the activity is generated as new knowledge (Cole & Engeström, 1993; Engeström et al., 1999). Rules, which may be loose or rigid, are the regulations that govern the community in which the activity occurs, and may provide the subject with guidance on the correct procedures and acceptable interactions with other members of the community (Cole & Engeström, 1993; Engeström, 2001). Division of labor is understood to be the roles of and tasks shared among the community members (Engeström et al., 1999; Fujioka, 2014; Juffs & Friedline, 2014; Yamagata-Lynch, 2010b). For example, students enrolled in an online mathematics course comprise the community where in the class syllabus and class procedures are the rules. The community's roles as learners, web browsers, and online consumers/contributors are the divisions of labor for the community. The arrows in Figure 2.3 indicate the dialectic relationships between each component of the activity system and the contradictions or tensions that may arise between them. These internal tensions are the motivating forces of change and development (Engeström et al., 1999). Transformations,

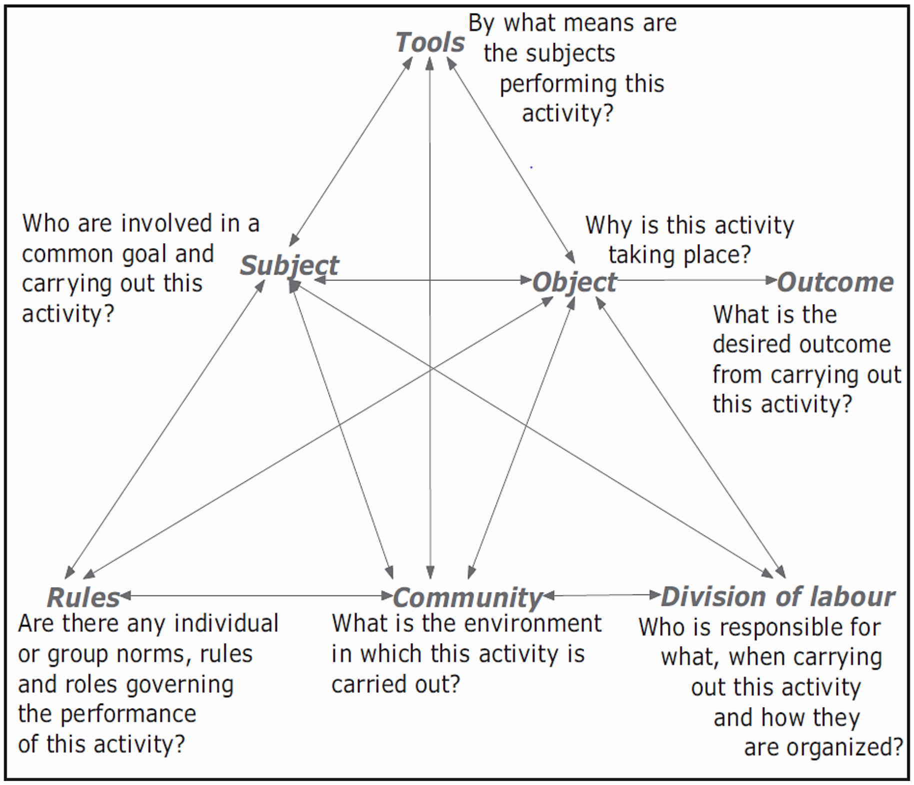


Figure 2.3. Engeström second generation activity system (Zurita, & Nussbaum, 2007).

i.e. changes, are possible when internalization, the reproduction of culture is converted to externalization in the form of a new artifact or object (Engeström et al., 1999).

Third generation Activity Theory. It was these tensions and transformations that led Engeström's development of the third generation of Activity Theory (1999). The third generation of Activity Theory examines the interaction between multiple activity systems created by one individual or with a group of learners (Figure 2.4). (Engeström et al., 1999, 2001). A network of activity systems need not apply to different learners. One learner may develop several activity systems that interact through reorganization and transitions, thereby modifying the community, the mediated artifacts and/or the object through mediated activity.

Engeström (1999, 2001) proposed the development of conceptual tools to understand dialogues, multiple perspectives, and networks of interacting activity systems. In the third generation of Activity Theory, Engeström (2001) viewed the network of activity systems as the unit of analysis, drawing on the ideas of dialogicality and multivoicedness (a community of

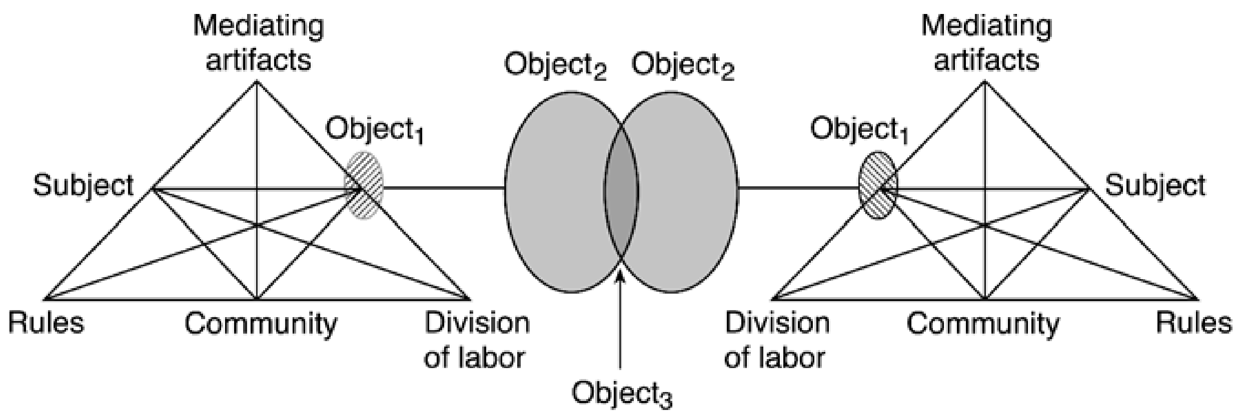


Figure 2.4. Third generation Activity Theory of two interacting activity systems as a minimal model (adapted from Engeström et al., 1999).

multiple points of view, traditions, and interests) to expand the second generation models and theorizations (Engeström et al., 1999, 2001).

Activity systems are open systems; when an outside element such as a new technology is introduced, it may lead to contradictions with previous rules or divisions of labor. These contradictions create obstacle for the subject in attaining his/her goal. These obstacles are addressed by transforming the activity system, consequently, creating new roles and community. The new community and new roles further transform how the technology is mediated (Engeström et al., 1999, 2001). For an emergent bilingual, their encountering unfamiliar Spanish

dialects or translations may create a contradiction with the translation capabilities of an intelligent tutoring system.

Intelligent Tutoring Systems

In the United States, first-generation online mathematics courses were created by converting lecture notes into PowerPoint presentations or posting videos of lectures on Learning Management Systems (Engelbrecht & Harding, 2005; Harasim, 2012; Stankov, 2010). Thus, first generation online mathematics courses were based on face-to-face curriculum and content (Harasim, 2012). The advent of sophisticated multimedia interactive software allowed for a more dynamic, collaborative and globally accessible learning environment (Caplan, 2008). Currently, most online mathematics courses have three modes of instruction: Static Web-Based Tutoring (WBT), Personalized WBT, and Adaptive WBT (Stankov, 2010).

Static Web-Based Tutoring mode is text-based delivery, where class materials are sent to students via email or placed on internet web pages for all students to read and complete. Lessons are provided sequentially as they would appear in a face-to-face course. In this mode, the material is posted online and must be read and interpreted by the student. Assignments are required to be posted or emailed to the instructor by certain due dates which again mimic a face-to-face environment (Stankov, 2010).

Personalized WBT utilizes Computer-Assisted Instruction (CAI) or a Learning Management System, such as Blackboard or CANVAS, to monitor student's online activities and provide learning objectives for students. Most CAI systems were developed for drill-and-practice approaches and are based on behaviorist learning pedagogy (Harasim, 2012). CAI provides instructors with added flexibility over face-to-face classes with additional comprehensive instruction (Stankov, 2010).

This mode of instruction, personalized WBT, allows students to utilize an electronic textbook, accompanied with an online homework system or CAI. An online homework system is a software, typically developed by the textbook publisher, to deliver and grade exercise problems. The software provides a platform for videos, tutorials and direct links between an exercise problem and sections in the book. However, this mode of instruction does not factor with different types of learners. A CAI system does not have the ability to determine which topics students may be struggling. Thus online educational software developers utilized cognitive learning theory to understand how knowledge is processed by the student (Ormrod & Daivs, 2008) in order to create adaptive intelligent tutoring systems (Harasim, 2012).

Adaptive WBT is an online course that utilizes adaptive intelligent tutoring systems. An intelligent tutoring system is a software program that utilizes cognitive and constructivist learning theories for mastery learning of the course domain. Intelligent learning systems are programed with pedagogical strategies and cognitive tutoring capabilities (Harasim, 2012). Several intelligent tutoring systems use Vygotskian sociocultural theories to create a space in which the learner makes meaning and constructs an understanding of the course topics (Borthick, Jones, & Wakai, 2003; Harasim, 2012; Salomon, Globerson, & Guterman, 1989). Intelligent tutoring systems must have knowledge of the domain, learner knowledge, and teaching knowledge to be considered for adaptive WBT (Harasim, 2012).

Knowledge of the domain requires that the intelligent tutoring system has error-free knowledge of all course content. The system must also be able to present, explain and deliver examples of all course content without error. Learner knowledge is defined as how the intelligent tutoring system assesses the student's current understanding of the course content (Harasim, 2012). Finally, teaching knowledge is the intelligent tutoring system's ability to determine what

portion of the curriculum the student should see next and how it should be presented (Harasim, 2012; Stankov, 2010).

Intelligent tutoring systems incorporate techniques from artificial intelligence and probability to intersect these three modes of knowledge. Probabilistic “and/or” statements and graphs are used to determine which topics a student has comprehension of and which should be presented to the student to learn (Falmagne et al., 1990). The software then directs the student to content she is ready to learn or to review material, depending on the student’s response to a previous question. A key aspect of intelligent tutoring systems is their ability to individualize learning activities to learners’ needs (Harasim, 2012).

One of the first intelligent tutoring software programs developed was SCHOLAR, an intelligent computer-assisted instruction program created by Jaime Carbonell in 1970 (Stankov, 2010). This software was considered the first intelligent tutoring systems due to its extensive use of the domain knowledge to provide individual tutoring. Other examples of early intelligent tutoring systems are SHERLOCK, which trained Air Force electronic technicians to diagnose problems in devices used to service F-15 jets, and Cardiac Tutor, which trained medical personnel on how to perform cardiac life support techniques (Stankov, 2010).

There have been several intelligent tutoring systems developed for teaching and delivering mathematical subjects. Houghton Mifflin Harcourt developed an intelligent tutoring system called Fuse for use on iPads. Pearson developed Knewton and Revel. Knewton is a diagnostic based software, while Revel is a new software that Pearson is developing to work with social media software such as Facebook (Oremus, 2015). ALEKS, developed by McGraw-Hill, is the intelligent tutoring system utilized by participants in this study, who were registered in a fully online pre-calculus class.

ALEKS: Knowledge Space Theory

The creators of ALEKS, software engineers and mathematicians, describe it as an artificially intelligent assessment and learning system (ALEKS, 2016). ALEKS is built on sophisticated concepts from combinatorics and stochastic processes in forming distinct knowledge states for students (ALEKS, 2016).

ALEKS uses adaptive questioning to quickly and accurately determine which topics have already been mastered by a student. After 20-25 questions, the software determines what sets of questions the student can answer, identified as their "knowledge state." ALEKS avoids multiple-choice questions thus providing course materials that are comprehensive in their topic coverage. Most importantly, ALEKS provides each student with an individual learning path. A student may follow the path that ALEKS determines based on her initial assessment, or she can choose and continue on a different path by selecting another topic, so long as the student has mastered all prerequisite material. As a student works through an ALEKS mathematics course, ALEKS periodically reassesses the student to ensure that topics learned are retained and to determine a student's most current knowledge state.

In *Mind in Society*, Vygotsky (1979) defined the zone of proximal development (ZPD) as: "…the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (p. 86). Many intelligent tutoring systems such as ALEKS implement a variation of Vygotsky's zone of proximal development (Borthick, Jones, & Wakai, 2003; Harasim, 2012; Salomon, Globerson, & Guterman, 1989). In ALEKS the mediation of an adult, tutor, or teacher is replaced by the intelligent tutoring system.

Vygotsky (2060, 1979) opined that students learned best when given problems that are just beyond their current knowledge level but can be accomplished through the guidance of an instructor or tutor. According to Harasim (2012), learning takes place when students solve problems beyond their actual developmental level under adult guidance or in collaboration with and instructor or peer. ALEKS scaffolds student learning by providing explanations, practice exercises, diagrams, graphs and formative assessments. ALEKS also provides students with lecture videos and an electronic, or “e-textbook,” specific problems are digitally linked to corresponding sections in the electronic-textbook. ALEKS defines a student’s zone of proximal development as his or her knowledge state, which is determined by the practice questions a student answers correctly.

Knowledge Space Theory posits that a student’s ability to answer a set of questions is preceded by an understanding of prerequisite questions and the probabilities of answering these questions correctly. A “domain” is a set of mathematical questions large enough to provide an exhaustive coverage of a subject or field. A “knowledge state” is a subset of questions in the domain that a student can answer when the student is working without outside stress, such as time frames, or exam anxiety (Falmagne et al., 1990).

Knowledge state. In ALEKS, the set of all questions that represent the topics of a course in its entirety is called the domain. Any collection of subsets from this domain is called a “knowledge state.” For example, as shown in Table 2.1, a set of problems in a linear functions chapter for pre-calculus, constitutes a knowledge state in ALEKS. At any given moment during the semester, a student will be working within their individual knowledge state or zone of proximal development (Vygotsky, 2012). Before a student can begin working on their individual

knowledge state and continue on their learning path, ALEKS must determine a student's initial knowledge state based on how they perform on an initial assessment.

Table 2.1

Six Types of Problems in Linear Functions Chapter for Pre-Calculus

	Name of problem type	Example of instance
a	Word problem on proportions	A car travels on the freeway at an average speed of 52 miles per hour. How many miles does it travel in 5 hours and 30 minutes?
b	Plotting a point in the coordinate plane	Using a pencil, mark the point at the coordinate (1,3).
c	Multiplication of monomials	Perform the following multiplication: $(4x^4y^2)(2xy^3)$
d	Greatest common factor of two monomials	Find the greatest common factor of the expression $14t^4y$ and $4t^2y^4$. Simplify your answer as much as possible.
e	Graphing the line through a given point with a given slope	Graph the line with slope -7 passing through the point $(-3, -2)$.
f	Writing the equation of the line through a given point and perpendicular to a given line.	Write an equation for the line that passes through the point $(-5, 3)$ and is perpendicular to the line $8x + 5y = 11$.

Initial Assessment. Before a student can begin working on practice problems provided by ALEKS, the program requires students to complete an initial assessment to determine their initial knowledge state, which is depicted by a pie chart, "ALEKS Pie," (Figure 2.5). Since a student's prior knowledge in mathematics will determine their initial knowledge state, students will each see a unique ALEKS Pie depicting their individual knowledge state. That is, each student will occupy their own unique zone of proximal development (Vygotsky, 1986). ALEKS periodically assesses the student, with a 20-25 question "knowledge check" to ensure that topics practiced have been mastered. After each knowledge check, the student's knowledge state is re-evaluated and a new learning path is provided to the student.

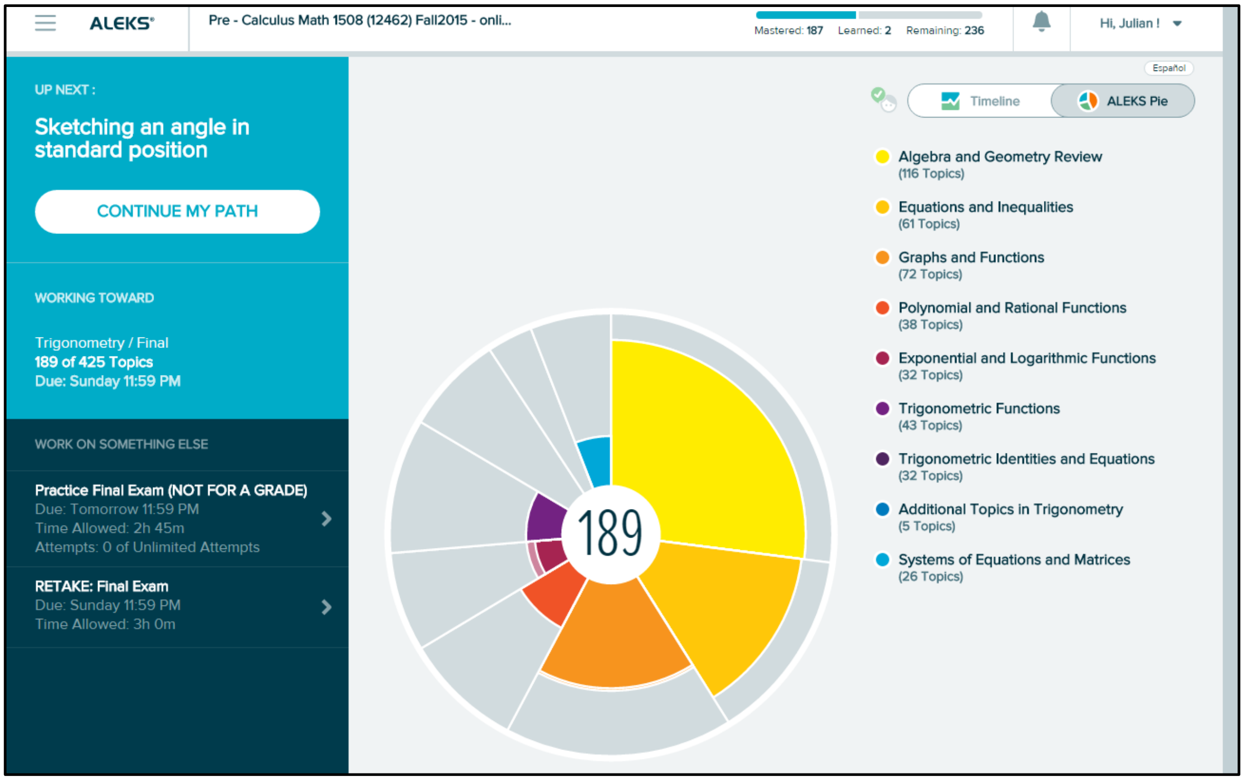


Figure 2.5. An ALEKS Pie for a Pre-calculus course.

Learning path. ALEKS determines an individual learning path consisting of practice problems and formative assessments for each student. Successful completion of three consecutive practice problems represents mastery of a topic (ALEKS, 2015); accordingly, the ALEKS Pie will begin to "fill up." This is depicted by the highlighted regions in each section of the pie in Figure 2.5. While working on a practice problem, students have the option to click on an "explanation" button to view a step-by-step procedure of the solution. The explanation button has graphs, diagrams, figures, and text for the student to read and understand. Once the student is satisfied with the explanation, they click on "more practice" to move onto solving a similar problem.

If the student does not understand the explanation provided by ALEKS, they can search the e-text that is linked to the topics in ALEKS by sections and chapters, and read the textbook explanations and example problems. Students can also click on a tutorial video if one is provided for the topic; however, these videos do not work with the translation function in ALEKS, nor are they dubbed or subtitled in Spanish. Students work on the practice problems until a knowledge check is automatically generated by ALEKS to determine which practiced topics have been mastered.

Analyzing the sample of linear function problems in Table 2.1, we see that there are 10 learning states, beginning with the empty set, $\{\emptyset\}$, which represents zero knowledge of this subset of problems and ending with mastery of the entire set of problems, $\{abcdef\}$,

$$K = \{\emptyset, a, b, ab, ac, abc, abcd, abce, abcde, abcdef\ \}.$$

Students may follow the learning path which ALEKS has determined for them or they can choose a different path by selecting an alternative topic, so long as the student has mastered all prerequisite material. Each of the subsets from Table 2.1 is assigned a probability that measures the likelihood a student will reside in a certain knowledge state. If a student answers problem f in Table 2.1 correctly, then the probability that this student has an understanding of all prerequisite problems is high. A conditional probability is assigned to the case where a student answers one of the questions in the domain correctly given that this student is in a knowledge state that does not contain this question. The learning path defined by this conditional probability is different from the learning path that arises when a student does not answer a question outside his/her knowledge state., Hence, within ALEKS, students do not learn the material linearly, e.g. they may progress, $a\ \rightarrow b\ \rightarrow c \rightarrow e$.

When a student masters all five problems in the domain, this creates her "knowledge space," i.e., the subset of domains mastered by the student. Creating a knowledge space is accomplished through individual learning paths. Figure 2.6 depicts the multiple learning paths students may follow to create their knowledge spaces (Falmagne et al., 1990).

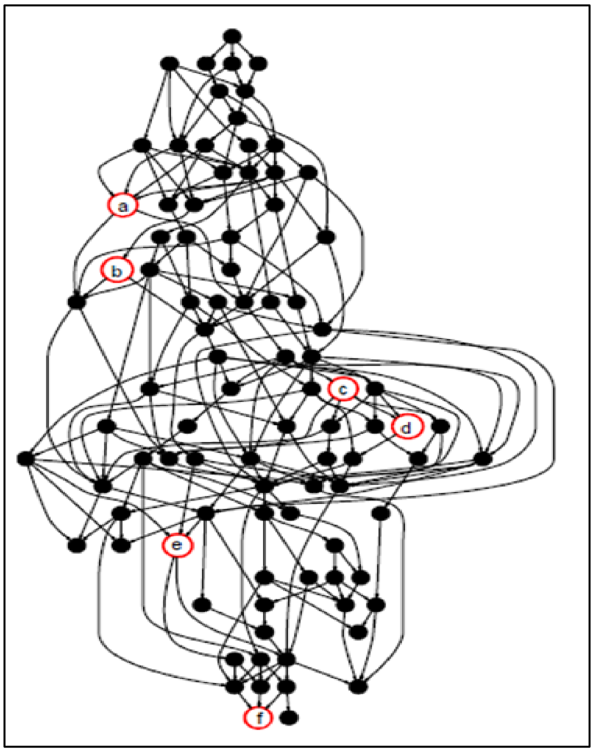


Figure 2.6. Diagram of learning paths for related topics for pre-calculus. The points marked *a-f* refer to Table 2.1 (Falmagne, et al., 1990).

Knowledge checks. After completing 20-30 topics or 10-12 hours on ALEKS, students are required to complete a "knowledge check," to ensure mastery of the completed topics. A knowledge check is a 20-25 question formative assessment that is automatically produced by ALEKS. ALEKS formatively assesses students while following their learning path to ensure they have mastered the topics they have practiced. These formative assessments follow Markov chain procedures to determine the next question a student will see after answering the first one.

There are two prompts for a knowledge check. One assessment is called a “progress assessment” and is generated for a student as mentioned above (after he/she has completed 20-30 topics or has logged into ALEKS for over eight to 10 hours). If a student has not logged into ALEKS for several days, then the program triggers the second type of assessment, the “Login Time Assessment.” The Login Time Assessment determines which topics from their last login the student has retained in their long term memory. If a knowledge check question is answered incorrectly, then the corresponding topic(s) will be added to the ALEKS Pie for the student to re-practice and re-master. Students complete the practice problems and take the formative knowledge checks until they have completed all topics or until the semester ends.

Evaluating the Effectiveness of ALEKS

A literature search was conducted using Google Scholar, Academic Search Complete (EBSCO) and JSTOR in order to identify empirical studies reporting the outcomes of using ALEKS in different learning programs. These learning programs included summer bridge programs for high school juniors and seniors, one-year programs, and college remedial courses. The literature search was restricted to studies published between the years 2002 through 2014. The purpose of the search was to discover the effectiveness of ALEKS in terms of improving college placement, standardized test scores, and grade, as well as how emergent bilingual students worked with ALEKS. Examples of the search terms used include “English Language Learners,” “ALEKS,” “intelligent tutoring systems,” and “cognitive tutor in math courses.” A second wave of publications was identified by searching the references of articles found through the first procedure.

A total of 13 research reports were identified and reviewed (see Appendix I). Several of these reports were not published in peer-reviewed journals but were presented at national

conferences of renowned associations, (e.g. the American Educational Research Association, American Society for Engineering Education, and Chair Academy Leadership Conference). The findings of these studies regarding the effects of ALEKS on students, course placement, and standardized test results are summarized in Appendix I and discussed below.

No increase in grades or course placement. Several studies found no significant increase in test scores or college placement of students who used ALEKS in comparison to students in traditional lecture classes (McClendon & McArdle, 2002; Spradlin, 2011; Xu, Meyer, & Morgan, 2009). In a study by McClendon and McArdle (2002) Florida community college students enrolled in an elementary algebra course without in-class lectures. Through the collaboration of the researchers and instructors, it was determined that lectures were not necessary due to the fact that students followed unique learning paths. Instead of lectures, students were expected to complete ALEKS topics corresponding to an elementary algebra class. The study found that when compared with traditional lecture courses, ALEKS students did not show a significant increase in their grades in the elementary algebra class nor subsequent math courses.

The authors noted that the ALEKS course was the only course available to students who registered late. As a consequence, several students did not have a choice as instruction mode. The researchers felt that this was a key limitation and potential confounding factor that may have undermined the validity of their efficacy results (McClendon & McArdle, 2002, p.12).

Next, the researchers conducted a survey of student’s attitudes towards the ALEKS software. In the survey, students stated that ALEKS was a better resource for the course material and of a higher quality a traditional printed textbook. One student made the following comment: “ALEKS offered me much more than a book could have.” When asked how the course could be

improved, another student responded: “All I can say is at the beginning of the semester I really hated ALEKS, but once I got used to it and buckled down I really enjoyed learning from the program” (McClendon & McArdle, 2002, p.20). As these statements and the results of the survey suggest, the ALEKS program allowed students to interact with the mathematics, through videos, hyperlinks to vocabulary definitions, and instantaneous explanation, that a printed textbook cannot provide.

In a graduate statistics course for education majors, Xu et al. (2009) utilized ALEKS to compare delivery of instruction from a face-to-face lecture class with a hybrid format. Forty-five students enrolled in the face-to-face lecture class in fall 2005 and 41 students enrolled in the hybrid class in fall 2006. Each course was taught by the same instructor utilizing identical homework assignments, quizzes, and exams. The hybrid class differed from the traditional lecture class in that it had fewer required class meetings, but did offer optional class meetings. Students in both class formats were required to complete homework from the textbook that was connected to the daily lectures. They were also required to work on the ALEKS topics. As in the previous research study, no increase in grade improvement was noted between the two formats (Xu et al., 2009).

Moreover, students in this study became frustrated with ALEKS for several reasons. For one, students in this study felt that ALEKS was time-consuming and that the ALEKS topics did not match the sections in the textbook. The most common frustration came from the formative assessments. As stated by the following student:

> Let’s say in that 5 hours, I’ve completed 9 topics or something like that…so, then at the end it gives me an assessment… so I’ve gone 9 topics ahead, but [the assessment] knocks me back 19…so, it’s just sort of like…you know,

> you just want to throw your pencil down and rip your hair out…you're just like, you know, I just kind of *wasted* 5 hours. (Xu et al., 2009)

Students also felt that their ALEKS learning paths were out of sequence with the lectures. Although students in the hybrid class had fewer classes to attend, they too encountered difficulties in completing the ALEKS topics and the textbook assignments. The researchers indeed found that students' learning paths on ALEKS were not in line with the lectures and daily class objectives. The researchers noted:

> …the instructor allowed several students to give up on ALEKS and concentrate on the textbook materials after the second midterm exam because they were so behind with an overwhelming number of topics to "relearn." This change shed doubt on the consistency of the study design, but it was done in the interest of the students (Xu et al., 2009).

Although Xu, et al. (2009) found no statistically significant increase in grades using the hybrid format they noted that the students who performed better were those who attended the optional classes more often.

In a study by Spradlin and Ackerman (2011), students enrolled in four Intermediate Algebra courses taught with traditional lectures, homework, quizzes and exams. In addition to the homework and quizzes, students in the experimental groups were required to complete course topics on ALEKS. Traditional homework assignments, which followed daily lesson plans and curriculum, were assigned on a separate online homework system. ALEKS was strictly utilized by students outside of the classroom and without instructor intervention or assistance, once more students found it difficult to combine their individual learning path and the daily class instruction and homework. Although Spradlin and Ackerman (2010) found no significant difference in

mathematical performance measured by a pre and post-test of Intermediate Algebra, they did find that an increase in test scores was associated with more time spent on ALEKS.

Increase in performance or placement. In contrast to studies reporting that ALEKS had no significant increase on grades or course placement, there were several in which ALEKS was shown to be effective (e.g. Barrus et al., 2011; Reisel, Jablonski, Hosseini, and Munson, 2012; Fine, Duggan, & Braddy, 2009; Goldberg & McKhann 2000; Hagerty & Smith, 2005; Hagerty et al., 2010; Hampikian et al., 2006, 2007; Taylor, 2008). Several of these studies are highlighted below.

Two studies from Boise State University utilized ALEKS in a pre-calculus and calculus course (Hampikian et al., 2006, 2007). Both studies reported on the creation of an engineering course, ENGR 110, which was taken concurrently with pre-calculus. In the 2006 study, 17 students out of a total of 118 pre-calculus students registered for an ENGR 110 course in which they met for 5.5 hours per week. Of these 5.5 hours, students spent 3.6 hours working on ALEKS in a classroom setting. Students were required to spend an additional three hours on ALEKS outside of the classroom and to complete six % of the topics remaining on their PIE (Hampikian et al., 2006)

The researchers found that students who worked on ALEKS outperformed non-ALEKS students by 11-grade points. These students also reported that they felt ALEKS impacted their grade positively. Thirty-one out of 94 calculus students were also required to enroll in a supplementary engineering course, ENGR 120. ENGR 120 was a ten-week course in which ALEKS was the major instructional component for the course. Students were required to work on ALEKS four hours per week. Again students who were enrolled in ENGR 120 performed better than those not enrolled in this course (Hampikian et al., 2006).

Hampikian et al. (2006) also conducted surveys to measure students' perceptions of both ENGR 110 and ENGR 120. Sixty percent of the ENGR 110 students had a favorable response to the course. They further indicated that they felt ALEKS was the reason for improvement in their grades and learning. When students were asked how they would structure the class in the future, 56% recommended continuing to use ALEKS in a similar way. However, although students felt ALEKS had a positive impact on their learning, they encountered frustration while working with the program. The researchers noted that when queried about the most annoying aspect of the course, the majority of the responses, fifty-seven percent of the written responses, were that ALEKS was the most frustrating aspect of the course (Hampikian et al., 2006).

In the ENGR 120 course, 30% of the students were very enthusiastic in their reviews of ALEKS. These students wanted to continue working on ALEKS after the required 10 weeks had terminated. They felt they were learning more material at an increased pace than they would have in a traditional class. Approximately 35% of the students felt neutral about ALEKS. However, when these "neutral" students were pressed on their reaction, they indicated that ALEKS might have helped them in calculus I. An additional 35% felt that ALEKS was a waste of their time. The researchers did not pursue the reasons why students felt ALEKS was not worth the time they spent working on it.

The 2007 study focused on ENGR 110 and the effect ALEKS had in pre-calculus (Hampikian et al., 2007). A learning community was created with students registered for pre-calculus, ENGR 110, and an English course. Students were recruited and registered into these learning communities through summer freshman orientation. The ENGR 110 class met for 5.5 hours per week, as in the previous study. This study differed from the 2006 study in that students spent most of the 5.5 hours in class working on ALEKS.

The first hour of the course was dedicated to university issues for new students; "…general instruction on aspects of the university and adapting to college life…Adapting to College Norms and Values; Classroom Expectations, Getting to Know Your Campus, General Study Skills and more…" (Hampikian et al., 2007, p. 5). The remaining hours were reserved for ALEKS. In contrast to the Xu et al. (2009) study, Hampikian et al. (2007) reported that after several weeks their students requested to opt out of the first hour of coursework, so they could concentrate their full attention on ALEKS. Moreover, based on students' overall grades in the pre-calculus course, the results of this study showed that mean math scores were higher for ALEKS students than for non-ALEKS students in pre-calculus.

Barrus et al. (2011) and Fine et al. (2011) report that ALEKS may lead to an improvement in course placement for high school seniors prior to entering college. In both studies, students were required to work on ALEKS in a computer lab where teachers were available to answer questions or provide mini-lectures to one or more students. Fine et al. (2009) studied high school seniors who had placed into a remedial math course. These seniors enrolled in a yearlong algebra class at their high schools. In the study by Barrus et al. (2011), participants enrolled in a highly structured 14-day summer bridge program. The summer bridge participants logged onto ALEKS a minimum of 3.5 hours per day. Participants did not receive lectures due to the fact that individual students were following their own unique learning paths as determined by ALEKS; however, teachers were readily available in the computer labs.

Both studies (Barrus et al., 2011; Fine et al., 2011) showed that utilizing ALEKS in an algebra class improved high-school seniors' college math placement. In addition, Barrus et al. (2011) specified that this improvement also included an increase in students' whose remediation requirement was removed.

Reisel et al. (2012) also report on the impact of a bridge program involving ALEKS. In 2007, the University of Wisconsin-Milwaukee developed a summer bridge program to improve students' mathematical course placement. Students were given two choices of the program, a four-week online version or an on-campus face-to-face one. Both the online program and the on-campus classes utilized ALEKS as the main teaching and delivery software. The on-campus program was found to be more successful at increasing math placement for incoming freshman. After two years the on-campus program had a 74% success rate in increasing students' placement compared to 46% increase for the on-line program (Reisel et al., 2012). In 2009 the online version of the program had been eliminated. The authors felt students were able to spend more time on ALEKS and were more focused and motivated in the on-campus program.

The on-campus program required students to attend classes at specific times each day (AM sessions) and work on ALEKS. Instructors were available in the classroom to answer questions as needed. Students spent two and a half hours working on ALEKS in a computer lab, while their progress was continually monitored by instructors through the ALEKS' progress reports. Students were also encouraged to continue working on ALEKS during their free time, away from the computer class (Reisel et al., 2012). The on-campus program, which offered students the ability to work on ALEKS in a computer lab with instructors available for intervention, was successful in increase students' math placement.

This review of the literature found that many studies reported an increase in grade, course placement, or standardized test scores and explained in detail some of their designs and findings. However, in several of these studies (i.e., Callahan et al., 2008; Hampikian et al., 2006, 2007; Hrubik-Vulanovic, 2013; and Reisel et al., 2012) the improvement was not statistically

significant. Those studies that did show statistical increases in placement scores did so with small sample sizes (e.g. Fine et al., 2009; Barrus et al., 2011).

Comparing and contrasting studies. Numerous studies researched the intelligent tutoring system, ALEKS, as the primary teaching utility, whiles others used ALEKS as a supplement to traditional lecture classes or in hybrid classes. In several studies, the traditional and hybrid classes required students to work on ALEKS in addition to working on homework assigned from textbooks, in-class quizzes, and written exams. Most control classes in these studies were in a traditional lecture format with traditional homework assignments and quizzes. What set some studies apart from those that reported no-significant differences was the implementation of ALEKS as the focus of instruction and delivery, supplemented by teacher intervention.

For example, Hampikian et al. (2006, 2007) did show a statistical increase in grades associated with the use of ALEKS and report that this increase seems unrelated to whether ALEKS-focused instruction is supplemented with lecture. In the studies conducted by Hampikian et al. (2006, 2007), students were provided individualized mini-lectures in a computer lab setting where all participants worked on ALEKS. Therefore, the lecture component seems unrelated to the increase in improvement among the ALEKS-focused students.

Hagerty et al. (2010) allotted one class session per week for students to work on ALEKS in a computer lab. During this lab time faculty answered individual questions or worked out examples for smalls group of students. Hampikian et al. (2006; 2007) also provided students with opportunities to ask for assistance while working on ALEKS. This strategy of providing one-to-one assistance while students worked on ALEKS was common to both studies, which each showed an increase in grades and placement (Hagerty et al., 2010; Hampikian et al., 2006, 2007).

Another overall difference between ALEKS studies was the time allotted for students to work on the program (Fine et al., 2009; Goldberg & McKhann 2000; Hagerty et al., 2010; Hagerty & Smith 2005; Hampikian, et al., 2006, 2007; Stillson & Alsup, 2003; Taylor 2008; Xu et al., 2009). This incorporated both working on practice problems and completing the periodic formative assessments. Stillson and Alsup (2003) did not require students to spend a set amount of time on ALEKS, yet they did find that students who spent more time working on ALEKS had a better understanding of Algebra and passed the course. Studies which allotted additional time in class to work on ALEKS and/or required a set number of hour per week found that students were more successful in increasing grades or course placement (Fine et al., 2009; Goldberg & McKhann 2000; Hagerty, et al., 2010; Hagerty & Smith 2005; Hampikian, et al., 2006, 2007; Taylor 2008). A limited number of these studies had qualitative data to report and none of these studies identified emergent bilinguals as participants, nor did these studies address how language affected participants' engagement with ALEKS.

Emergent Bilinguals in Online Mathematics Courses

English language learners become bilingual, able to function in their native language as well as in English, through school and through acquiring English. English language learners or limited English proficient students are defined as students between 3 years and 21 years of age and are "enrolled in elementary or secondary education, often born outside the United State or speaking a language other than English in their homes, and not having sufficient mastery of English to meet state standards and excel in an English-language classroom" (as cited in García, 2008). Students who are acquiring English in American schools are also referred to as *English learners, culturally and linguistically divers, children with English language communication barriers, English as a second language, language minority, and bilingual.* Each of these labels

offers various positive and inclusive connotations. However, there is little agreement about which term best describes these students.

These terms for English language learners are rooted in historical and governmental policies created to serve this population (García et al., 2008). Researchers argue that using other terms to label this population of students perpetuates inequalities they encounter in their education and ignore native language and cultural understanding (Escamilla & Hopewell, 2010; García et al., 2008; Moschkovich, 2015). In fact, English language learners are emergent bilinguals, that is, English language learners who are acquiring the ability to continue to function in their native language as well as in English, their new and academic language (Escamilla & Hopewell, 2010; García, & Kleifgen, 2010; O’Conner & Crawford, 2015).

Emergent bilingual population presents many challenges for equitable education (O’Conner & Crawford, 2015). They are a diverse population who enter college at different levels of literacy. Instructions of higher learning must provide emergent bilinguals with the same opportunity to learn and develop English language skills as their native-English speaking counterparts. This is also true for mathematics.

Studies on emergent bilinguals’ as mathematical literacies, language behaviors and attitudes toward traditional math courses are widely available (Esquinca, 2011; Gutierrez et al., 1999; Moschkovich, 2007, 2015; Planas & Setati, 2009; Spence & Usher, 2007; Yushau, 2006). Research on emergent bilinguals’ digital practices in online mathematics courses has been largely unexplored. Studies of online mathematics learning fall into three subgroups of research focus: implementation of a mathematics online course (Anderson, 2008; Engelbrecht & Harding, 2005), self-efficacy (Freeman, 2012; Rivera & Waxman, 2011; Spence & Usher, 2007; Tahar, Ismail, Zamani, & Adnan, 2010), and learning attitudes (Canfield, 2001; Di Martino &

Zan, 2010; Muilenburg & Berge, 2005; Reed, Drijvers, & Kirschner, 2010). The demographic information these studies retrieved from participants focused on socio-economic status, gender and race. As a result, academic mathematical literacies and emergent bilinguals were not a primary focus of these research studies. Those studies that do describe attributes of effective online learning for English focus on language acquisition, and not on mathematics (Swan, et al., 2000; Tan & Hung, 2002).

Fully online courses are much more prevalent at the college level than they were a decade ago (Caplan, 2008). Online courses are also requested more by monolingual students (Caplan, 2008) as well as emergent bilinguals (Costa & Guerra, 2015). Marc Prensky (2001) conceived the term Digital Native in an essay in 2001 for *On the Horizon*. Prensky (2001) points out that today's students find it difficult to identify with the world bereft of the internet, video games, cell phones and digital devices for everyday use. These students see and think of their world differently than older generations.

Learners have developed hypertext minds that learn by jumping back and forth from internet tabs to digital devices and that allows them to make meaning of their learning, creating a multimodal learning environment (Prensky, 2001). A Digital Native is not a person born after a certain year; he/she is a person living and learning in a digital culture (Prensky, 2001). An online course may be an advantageous environment for an emergent bilingual digital native; nevertheless, the academic language domains that exist in online courses must still be negotiation through digital literacies.

Digital literacies have been referred to as the practice of relating, communicating, thinking, and meaning making with digital media (Gillen, 2014: Gilster & Gilster, 1997; Jones & Hafner, 2012). The practice of internet searching is not specific to hardware or software;

hypertextual navigation and content evaluation are methods that can be applied to online courses, including mathematics (Gilster & Gilster, 1997). A digitally literate individual can search the internet efficiently and differentiates between culturally relevant and irrelevant information (Bawden, 2008). These digital natives also multitask by utilizing a variety of digital tools, smartphones, tablets, and other digital devices to accomplish the goal at hand. The present research studied how digital literacies influence student's self-efficacy in mathematics.

A case study on the effective use of translating software into Spanish. In a study by Casas, Goodman, and Pelaez (2011), a group of Latin American and Caribbean (LAC) universities collaborated to develop and utilize technology to enhance math education from primary to the collegiate level. The participating universities, Pontificia Universidad Catolica de Chile (PUC), Escuela Superior Politecnica del Litoral de Ecuador (ESPOL), and Technologico de Monterrey, Mexico were led by Carnegie Mellon University. The purpose of this collaboration was to improve access to and quality of mathematics education in Latin American countries. At the time of this study, national and international test scores for these Latin American countries had not improved despite various interventions. This Casas et al. (2011) quantitative and qualitative study reported on changes in students' math performance in sixth through eighth-grade Algebra in classes that used a math cognitive tutor.

An algebra math cognitive tutoring system that followed a personalized self-paced approach was developed, "allowing students to sequentially tackle progressively more difficult tasks and freeing up teacher time to work with slower students and on more difficult problems" (Casas et al., 2011, p. 10). A feature of this cognitive tutoring system was that it provided diagnostic data that could be utilized to identify difficulties for learning and possible interventions for students. In this study, the teacher's role was to motivate students and to answer

questions while students worked with the software in a computer lab. In the classroom, teachers followed a traditional lecture with group work activities. An important step the creators of the MCT took when creating this software was that when translating the software from English to Spanish, they considered cultural and idiosyncratic differences in the language of each country (Casas et al., 2011).

This study found a statistical improvement in student's math scores, including improved scores on a national standardized test in Chile (Casas et al., 2011). Qualitatively, the authors found that 78% of the treatment group was satisfied with their math score improvement. Sixty-eight percent of the treatment group increased their motivation to do the math, while 82% of students said they would like to use a similar program for other subjects. Finally, 88% of students wanted to continue using computers in their classes. The researchers found these preliminary results to show that learning mathematics can be positively impacted by technology when converted to a student's native language (Casas et al., 2011).

Linguistic and Biliteracy Challenges

Research in biliteracy is an area of great interest in regions of the United States where school populations of Spanish-dominant emergent bilinguals are increasing. In the United States 19%-24% of all K-12 students are Latin@ and report that Spanish is their native language (Babino & Stewart, 2016; Santiago, Calderón Galdeano & Taylor, 2015). Many academic programs promoting biliteracy have become common in the national educational landscape (Gort, 2006). There are programs in transitional bilingual education, developmental bilingual education, Two-Way Bilingual Education, English as a Second Language, dual language, submersion, and structured immersion, each designed for language education and acquisition (Bialystok, 2001; García & Kleifgen, 2010; Gort, 2006; Hakuta & Cancino, 1977; Moschkovich,

2007; Zentella, 1997). Research in second language acquisition, bilingualism, and biliteracy provide theories, empirical results, concepts, and definitions necessary for the acquisition of a second language. However, research on the effectiveness of these programs continues (Bialystok, 2001; Hakuta & Cancino, 1977; Moschkovich, 2007; Zentella, 1997).

Drift towards English. Several studies in dual language education persistently find that English becomes more dominant in successive generations of immigrant children, perpetuating a sense of the inescapable hegemonic nature of English (Achugar & Pessoa, 2009; Freeman, 1998; Potowski, 2004: Volk & Angelova, 2007). Researchers have shown that for Latin@ immigrants, their mother tongue is all but lost by the third generation (Figure 2.7). (Babino & Stewart, 2016; Rumbaut, Massey, & Bean, 2006; Taylor, Lopez, & Martinez, 2012). There are a variety of political, social, and cultural obstacles supporting Latin@ students' investment in Spanish (Gonzalez-Carriedo, 2015; Rubin, 2014).

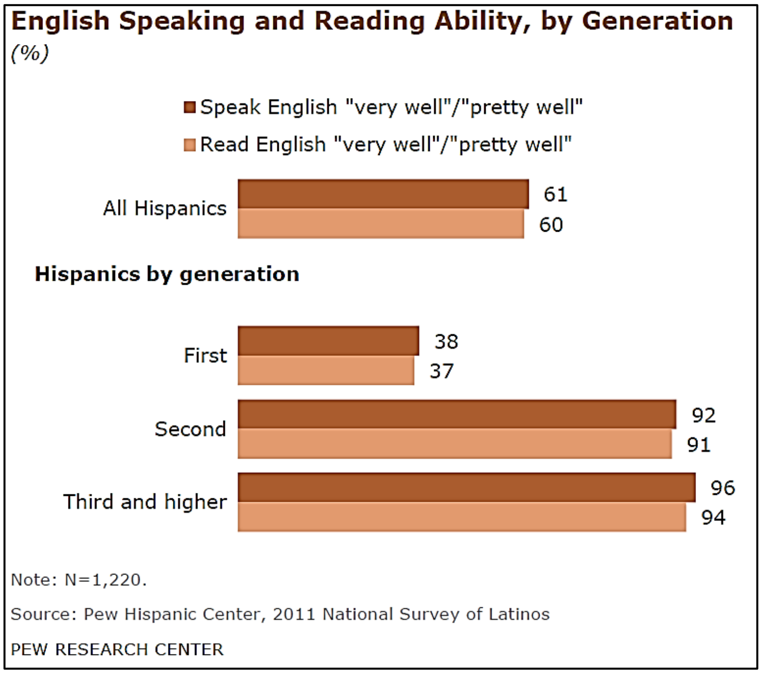


Figure 2.7. Pew Hispanic Center survey on English Speaking and Reading by Generation (Taylor et al., 2012).

One social and political obstacle is the belief of a proper language skill, identified as "standard language ideology," which Latin@s utilize to justify social differences and inequalities (Milroy & Milroy, 1985). Social differences brought about by the standard language ideology, occur within Latin@ communities with documented negative effects. In, particular, the standard language ideology can affect children's' self-efficacy in educational settings. When Latin@ children lose their first language, there are emotional, social, cognitive, and academic consequences which negatively affect not only the children but society at large (Babino & Stewart, 2016). Latin@s attitudes toward Spanish language/culture and bilingual education also affect their language practices and attitudes (Achugar, 2008). Babino and Stewart (2016) found that even though Latin@s enjoy using both English and Spanish in school, they prefer using English over Spanish in both academic and social settings.

There is a historical context for removing Spanish from a child's lexicon. Studies by Garcia (1981), Sánchez, (1993) and Richardson (1999) found that Mexican children in a U.S.-Mexico border city were not allowed to speak English while they attended school. Children were placed into "Mexican Schools" whose objective was the "Americanization" of Spanish speaking children through a curriculum designed to prepare these students for the labor force. Students were punished, corporally and/or emotionally, for speaking Spanish while at school (Arreguin-Anderson & Ruiz-Escalante, 2014). Children of Mexican origin did not see Spanish as an asset; thus for these children, their native language did not contribute to social mobility (Achugar, 2008; Sánchez, 1993; Richardson, 1999). Although this exact type of subtractive schooling is no longer in practice, many Latin@ students perpetuate the ideology of English as the international *lingua franca* with their belief that learning English is the key to academic and economic success (Achugar, 2008).

Taylor et al. (2012) found that nearly 87% of Hispanics believe learning English is important for economic success (Figure 2.8). As noted in several studies, students in dual language and bilingual programs drift towards English dominance (Ballinger & Lyster, 2011; Pomerantz, 2008; Potowski, 2004). According to Valdes (2004) students in dual language and bilingual programs feel pressure to acquire English, sometimes to the point of replacing their native language. If a society privileges the English language explicitly or covertly then dual language communities find it difficult to remove themselves from the values of the dominant society (Achugar, 2008).

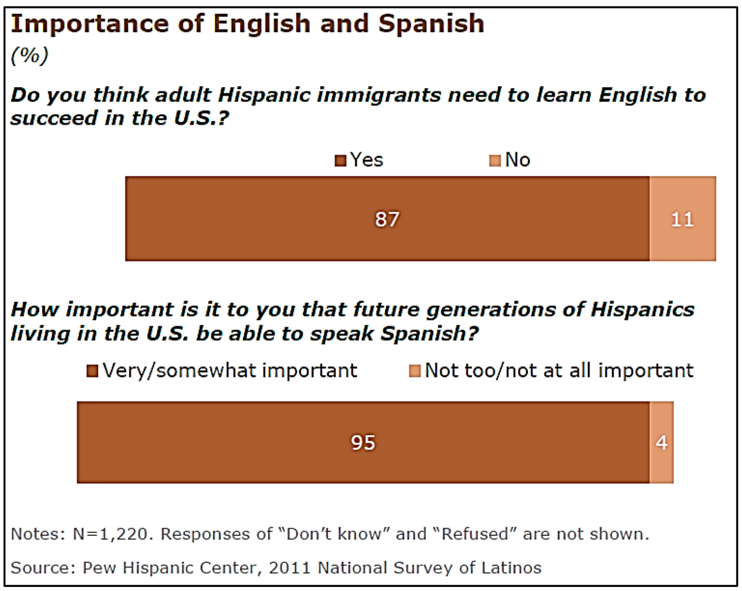


Figure 2.8. Pew Hispanic Center survey on the importance of learning English (Taylor et al., 2012).

The research literature on second language acquisition, bilingualism, and biliteracy is available and great in depth and scope (Bialystok, 2001; Gort, 2006; Hakuta & Cancino, 1977; Moschkovich, 1999, 2007; Zentella, 1997). An increasing number of researchers have moved beyond deficit theories and issues of assessment to the study of how emergent bilinguals can be

provided with a high-quality mathematics education (DeAvila, 1988; Gutierrez, 2002; Gutstein, Lipman, Hernandez, & de los Reyes, 1997; Khisty, 1997; Moschkovich, 1999, 2007). However, biliteracy theories and empirical results are not the focus of this literature review. Instead, mathematical literacy and utilizing bilingualism as an asset will be discussed in the next sections.

Mathematical biliteracy. Moschkovich (1999) made the following recommendation for teachers with Latin@ students in developmental math classes: 1) honor the diversity of Latina/o students' experiences, 2) know the students, 3) avoid deficit models, and 4) provide opportunities for mathematical discussions. Moschkovich (1999, 2007) and Gutiérrez et al. (1999) found that emergent bilingual students communicate mathematically through conjectures, presenting explanations, and constructing arguments about mathematical objects and content in order to make a mathematical conclusion. Hence, emergent bilinguals' experiences and prior knowledge provide them with an opportunity to learn mathematics and discuss mathematics only when teachers are aware of a student's lived stories and view them as capable learners. Placing students in groups where the level of English competency varies will help students comprehend mathematical terms and strategies as well as improve their English register. This corresponds to Gee's (2007) definition of discourse, which involves points of view, communities, and values.

Gardella and Tong, (1999) conjectured that learning mathematics is similar to the way children acquire language skills. Chaika (2008) stated, "acquiring language is very much a socially determined phenomenon. No child can learn an oral language without hearing one spoken" (p. 16). Hearing mathematical register and being allowed to translate or communicate such register in one's native language will aid in a student's mathematical comprehension. Students practice describing patterns, making generalizations, and using representations to support claims during peer discussions (Moschkovich, 2007).

Group work allows a student to form a community within the classroom that may be more homogeneous to their everyday culture, allowing for mathematics to appear as an everyday occurrence as opposed to a subject to fear (Moschkovic, 2007). Slavit and Ernst-Slavit, (2007) stated that collaborative group work would provide students with the opportunity to hear and use mathematical register while at the same time developing mathematical understanding. In such discourse students become more comfortable with mathematical register when the group has the feeling of community (Slavit & Ernst-Slavit, 2007). Developing a bilingual online community can also create an opportunity for acquiring mathematical register and mathematical literacy.

In a study of pre-service teachers, Esquinca (2011) found that pre-service teachers used *translanguaging*, meaning to switch rapidly between verbalizing in Spanish and English, to help them write text in English and to make multiple meaning-making resources for mathematical word problems. Literacy practices such as *translanguaging* and participating in discourse allow emergent bilinguals to learn mathematics (Moschkovich, 1999, 2007). Students will learn about mathematical situations, communicate about these situations and use vocabulary and resources for mathematizing and communication (Moschkovich, 2007).

Mathematical discourse provides emergent bilinguals an opportunity to move away from learning mathematics through “simplified views of language as words, vocabulary, or definitions” (Moschkovich, 2015, p. 58). In mathematics, academic literacy requires mathematical meanings that are negotiated and grounded in activity. Opportunities to refine these negotiated meanings should be provided in mathematical classes and be grounded in mathematical activity (Moschkovich, 2015). Moschkovich (2015) opines that these opportunities for meaning making for academic literacy in mathematics should be multimodal. This means including pictures, words, videos, symbols, tables, and graphs. Complex mathematical discourse

should also consist of various types of written texts along with exploratory and expository discourse.

Gee (2007) writes that word meanings are rooted in negotiations people have with different interests and social practices that nonetheless share a common ground. Emergent bilinguals are members of social communities that mediate meaning making in both English and Spanish. In an online environment, emergent bilingual digitally construct virtual communities. These online communities are created by emergent bilingual digital natives without knowledge of social, cultural and linguistic differences (Lotherington, & Jenson, 2011; Zheng, Young, Wagner, & Brewer, 2009). Negotiating meaning making in an online environment for mathematics is important for emergent bilinguals' sense of social and academic equity (Achugar, 2008; Gonzalez-Carriedo, 2015; Rubin, 2014) because they are aware that mathematical literacy is important for future course work as well as for future careers in the U.S. (Bates, 1997; Keister, Vallejo, & Borelli, 2015; Vallejo, 2009).

Kalantzis and Cope (2012) speak of the glass ceiling that may exist for those students who (1) do not learn the language of technology or (2) are not meaning producers as well as meaning consumers (Participant communicators). Lemke (1998) posits that literacies are themselves technologies and learning mathematics in an online environment for emergent bilinguals is a multimedia, multimodal endeavor. Online translators are multimedia programs that not only provide text translations but also translate speech, images, and videos. Carlson (2007) found using first language translations leads to vocabulary retention for emergent bilinguals. Combining these strategies with native language can make confusing mathematical concepts clearer (Lemke 1998).

Studies have shown that translating software into a student's native language is beneficial (Casas et al., 2011, p. 10); however, utilizing intelligent tutoring systems, the use of online translators and other meaning making activities require further study. Researchers agree that biliteracy and mathematical literacies can have a positive effect on emergent bilinguals' self-efficacy in mathematics courses (Achugar, 2008; Casas et al., 2011; Gonzalez-Carriedo, 2015; Gutierrez, 2002; Moschkovich, 1999, 2007; Remillard et al., 2005; Rubin, 2014). Studies on how translating digital mathematical software or utilizing online translators affect emergent bilinguals' self-efficacy have largely been unexplored.

Self-Efficacy

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; Spence & Usher, 2007; Tahar et al., 2010). These studies implemented factor analysis on student surveys and questionnaires in order 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 positive attitude and self-efficacy. Students were found to improve mathematical conceptual knowledge when they were allowed to use their preferred language. Emergent bilinguals have a preferred language when performing arithmetic computations, which is typically the language of instruction (Moschkovich, 2007). 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). This 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.

Learning Attitudes

Di Martino and Zan (2010) found that many studies define attitude towards mathematics implicitly and furthermore, that these definitions were of three types. These were: 1) a *simple* definition that attitude is positive or negative; 2) a *tripartite* definition that categorizes attitude into three components: emotional response towards math, beliefs about math and behaviors related to math; and 3) a *bi-dimensional* definition in which behaviors do not appear explicitly, with respect to the second type of definition. They suggested that research on attitude should change from a normative approach to an interpretative one. These authors encourage us to try to understand the motives behind intentional actions students take to achieve their goals.

Research on student attitudes towards mathematics has focused on positive and negative attitudes (Canfield, 2001; Muilenburg & Berge, 2005; Reed et al., 2010). Canfield (2001) surveyed students about whether they felt they had learned more using the intelligent learning system ALEKS, and what aspect of the course/software was most useful. Students did indeed feel that they had learned more mathematics while using ALEKS as the mode of instruction. As shown by Canfield (2001), a positive attitude correlated with positive responses to these questions.

Muilenburg and Berge (2005) and Reed et al. (2010) attempted to quantify student attitudes towards math and technology. An item analysis was performed in which positive attitudes towards math and technology were shown to be correlated with higher grades and course success. These studies determined that students with positive attitudes towards mathematics attained higher test scores and a better understanding of content.

Reed et al. (2010) found contradictory results, i.e., that students with a higher positive attitude towards mathematical computer tools had lower test scores in their mathematics courses. This complemented a study by Yushau (2006), who considered whether an online mathematics course improved students' attitudes towards math and computers. Utilizing the Aiken Mathematics Attitude Scale and the Loyd and Gressard Computer Attitude Scale, Yushau (2006) found no statistical significance in attitude improvement with an online math course. Although these studies focused on attitude and self-efficacy in math classrooms, they did not differentiate emergent bilinguals in their research.

Griffiths et al. (1994) found that the exclusion of a students' native language from technology meant to emergent bilingual students that their language was archaic and that their language was unable to deal with the modern world. They also found that having software in emergent bilingual students' native language built students' self-esteem and helped them learn more effectively. Emergent bilingual students have educational content knowledge from their home country or native language; translating mathematical vocabulary correctly can, therefore, be crucial to their success in mathematics courses (Griffiths, 1994; Moschkovich, 1999, 2007). In this same vein technology which can toggle from Spanish to English will allow students to learn vocabulary as they work on mathematical software (Griffiths et al., 1994).

It has become increasingly important to consider internet self-efficacy as a predictor of success in an online environment. Internet self-efficacy is defined as a belief in one's ability to organize and implement internet activities that produce the desired results (Kuo, Walker, Schroder, & Belland, 2014; Eastin & LaRose, 2000). Hence the importance of digital practices and activities is crucial for emergent bilingual students' success in online mathematics courses.

Implications of this dissertation study

Carpenter (2009) professed that any course that utilizes technology would be most effective if the utilization of the software has clear objectives and goals. Translating software into an emergent bilinguals' native language allows for the student to fully comprehend class objectives and goals. Research literature in the area of emergent bilinguals in mathematics classes has focused on self-efficacy, attitudes, and language use. Utilizing software translation capabilities and online translators give emergent bilinguals an opportunity to make meaning of English lexicon and mathematical register. Mediating these translation utilities will create a bilingual digital mathematics courses in which emergent bilinguals can acquire academic mathematical literacy. The mediation of translating online mathematics courses and making meaning of mathematical terms has not been fully realized in the existing research literature.

Albert and Mori (2001) stated, "learning is an adaptive process, the interactive e-learning system has to support this process by being adaptive itself" (p. 6). Students utilize internet translating sites, translating software, cell phone dictionary apps, bilingual friends, and tutors to make cognitive connections between text and mathematics. Emergent bilinguals adapt their digital activities to create a digital space for equitable educational opportunities. According to Prensky (2001):

> Today's students have not just changed incrementally from those of the past, nor simply changed their slang, clothes, body adornments, or styles, as has happened between generations previously. A really big discontinuity has taken place. One might even call it a "singularity" – an event which changes things so fundamentally that there is absolutely no going back. This so-called "singularity" is the arrival and rapid dissemination of digital technology in the last decades of the 20th century.

Thus instructors and developers of future online mathematics courses should consider the potential benefits of finding ways to take these changes into account. There is great potential in using technology to create authentic bilingual online mathematics courses: these courses could aid emergent bilinguals in achieving academic mathematical literacy by allowing them to mediate technology and translating software.

Summary of Chapter 2

This chapter was a review of the literature for this study. Activity Theory, Knowledge Space Theory, digital literacies, biliteracy, and Self-efficacy, form the theoretical basis for exploring the lived experiences of emergent bilinguals' participation and engagement in an online mathematics course. An overview was provided of online mathematics courses from their nascence up to their present dissemination. This chapter also summarized the evolution of Cultural-Historical Activity Theory, from its origins with Lev Vygotsky and socioculturalism through the current, third generation iterations by Engeström. Knowledge Space Theory, which borrows from socioculturalism and artificial intelligence, was also explicated.

This chapter also reviewed the research literature on the effectiveness of ALEKS in mathematics courses, as well as how emergent bilinguals have been studied in mathematics classes. This chapter also included a case study of research that examined the effects of

translating an intelligent tutoring system into students' native language, Spanish. This was included to situate the present dissertation research on emergent bilinguals' use of an intelligent tutoring system. Finally, a review of Self-efficacy Theory was presented and utilized to situate emergent bilinguals' digital practices and learning attitudes within the current literature.

This literature review provides confirmation that research on how emergent bilinguals engage in a fully online math course will best be accomplished through a mixed methods approach. It lays down a foundation for the methodology used in the present study. This includes the setting of a fully online pre-calculus course at a university in the United States, participant recruitment and selection, data collection and analysis, and the rationale for utilizing a mixed methods approach. These methodological components will be described in Chapter 3.

Chapter 3

Research Methodology

Overview

The literature review supported the necessity to better understand the digital practices of emerging bilinguals taking an online mathematics course as well as how these digital practices can affect their self-efficacy. A case study by Casas, Goodman, and Pelaez (2012) determined that translating an intelligent tutoring system into Spanish could have a positive impact on emergent bilinguals mathematical exam scores and national standardized test scores as well as their attitudes towards technology in a math class. Students in the aforementioned study reported an improved attitude towards the intelligent tutoring system and improved self-confidence in their ability to comprehend mathematics (Casas et al., 2012).

Monolingual intelligent tutoring systems have been found to be effective in improving student mathematics scores and improving college placement (Fine, et al., 2009; Goldberg & McKhann 2000; Hagerty & Smith 2005; Hagerty, et al., 2010; Hampikian, et al., 2006, 2007; McClendon & McArdle, 2002; Spradlin, 2011; Taylor, 2008; Xu, et al., 2009). In the United States, research on emerging bilingual students in mathematics courses focuses on self-efficacy, learning attitudes and English acquisition. This dissertation study contributes to the research literature on emerging bilinguals by illuminating their digital practices for understanding course instruction, mathematical terminology, and forming mathematical connections in both Spanish and English, Quantitative data was also collected and statistically analyzed to find an association between translating an intelligent tutoring system and emergent bilinguals' mathematical and technology self-efficacy.

This mixed methods embedded-exploratory design explored the experiences of emergent bilingual students in an online pre-calculus class over four semesters at the University of Texas at El Paso. Participants were identified as Spanish-dominant emergent bilinguals by their demographic survey responses and from English as a Second Language (ESL) courses taken in elementary and high school as well as at the university. This chapter details the procedures utilized to examine the research questions that guide this study. This methodology chapter outlines the setting, research population, selection of the population sample, research design, and collection and analysis of data for the study. This study and the analysis of the data is based on the theoretical framework outlined in chapter two.

Setting of Study

Participants in this study were recruited from students enrolled in a fully online pre-calculus course offered at the University of Texas at El Paso over four semesters: fall 2014, fall 2015, and spring and fall 2016. This university is a Hispanic Severing Institution (HSI) located on the U.S.-Mexico border. In 2014 the university was ranked among the top five universities nationally in the category of social mobility by *Washington Monthly* (Glastris, 2014). The university offers three freshmen-level online mathematics courses: Pre-calculus, Calculus I, and Math for Social Sciences I. The online Pre-calculus course was chosen because of its use of an intelligent tutoring system that can be translated into Spanish and for convenience sampling purposes.

The majority of students enrolled in this fully online mathematics course lived and logged on from the surrounding southwest region which populates the university. Approximately 83% of the university’s entire student population lives in the neighboring county. The majority of students enrolled in this fully online mathematics course lived and logged on from the region

surrounding the university. Students enrolled in this course logged on from various locations, for example, Wichita Kansas; Mexico City, Mexico D.F.; Phoenix, Arizona; Delicias, Mexico; Clint, Texas; and Dallas, Texas. The demographic composition of participants enrolled in this course was approximately 78% Hispanic/Latin@, 3% African-American, 1% Asian-American, 9% White/Caucasian, 0.22% Native American, and 0.14% other.

Math 1508 Pre-calculus description. Math 1508 is a one-semester pre-calculus course at the university. The main topics for this course are; algebra review, concepts of functions (general functions, exponential and logarithmic functions, polynomial and rational functions, and trigonometry functions), solving system of linear and non-linear equations and inequalities, evaluating basic matrix operations, solving exponential, logarithmic, and trigonometric functions and verifying trigonometric identities. Math 1508 is a fully online pre-calculus course which was first offered at the university in the 2010 spring semester, and the format of this course remained the same until 2017.

ALEKS. The dissemination of all mathematical content in this online pre-calculus course is through the intelligent tutoring system, **A**ssessment and **LE**arning in **K**nowledge **S**paces, better known by its acronym, ALEKS. The program requires several plug-ins when downloaded and is compatible with all Windows and Apple computers as well as personal digital devices such as smartphones and tablets. The program can be viewed with most internet browsers; however, some functionality is diminished when ALEKS is used with Internet Explorer. ALEKS utilizes adaptive questioning to accurately determine which topics a student has mastered at a given moment in time. That is, through machine-learning algorithms borrowed from artificial-intelligence concepts, ALEKS analyzes student’s responses to assessment problems and

determines what topics the student has mastered and what topics that student is ready to learn next.

A feature of the software that was crucial for this study is the fact that ALEKS can be completely translated into Spanish. By clicking on the drop down menu labeled “English,” the entire program can be translated into Spanish, except the video tutorials within ALEKS and the e-textbook linked to the course. These videos are resources provided by the digital, “e-textbook,” for the course (*Precalculus, Second edition, written by John W. Coburn*); both the videos and e-text are linked to content in the ALEKS course. Figure 3.1 shows a trigonometry topic, exponential and logarithmic functions, that has been translated by ALEKS into Spanish. The arrow at the top right in Figure 3.1 has been added to the image to indicate the drop-down menu students can click to toggle the program from one language to the other.

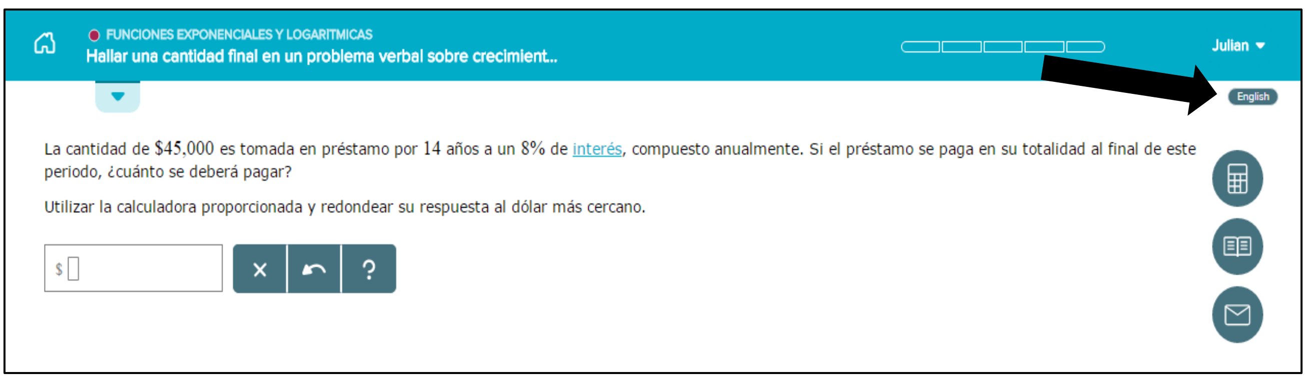


Figure 3.1. ALEKS Converted into Spanish by clicking on the drop down menu at the arrow.

Intermediate objectives in ALEKS. There were three graded modules in this course called intermediate objectives: Review Topics, Prep for Midterm, and Trigonometry (Figure 3.2). The Review Topics objective was weighted 5% of a students’ overall grade for this course. The Prep for Midterm was 10%, while the Trigonometry objective was worth 15%. Each intermediate objective grade was calculated by the percentage of topics completed by the due

date. For example, Figure 3.2 displays the intermediate objectives, number of topics completed, and the grade associated with each intermediate objective as of the image capture date (September 6, 2015). One can see from the image that 122 out of a possible 146 Review Topics had been completed by this particular student as of September 6, 2015; therefore the grade recorded for this student's Review Topics was 84% (122/146). In Figure 3.2 the due date

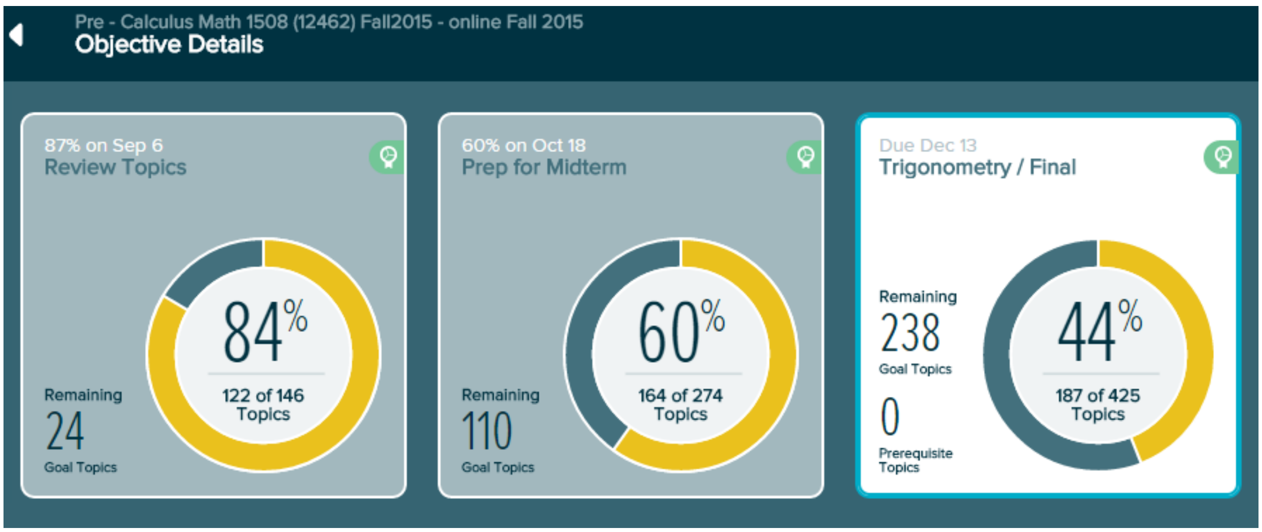


Figure 3.2. View and sample of Intermediate Objectives created in ALEKS for a fall 2015 section of the pre-calculus course.

for the final objective, Trigonometry, was still pending at the time this image was captured, so that box is not grayed out. This student had about two more months to complete additional topics from the trigonometry objective to improve his/her grade.

ALEKS Pre-Calculus Course Procedures. When students first log in to ALEKS they are required to complete a tutorial on how to enter solutions, work with the math pallet and graph solutions. Once the tutorial has been completed, students are given a diagnostic initial assessment, called the initial knowledge check, to determine their initial knowledge state. The duration of this 25-30 question initial knowledge check is typically one hour to an hour and a

half, depending on a students' prior knowledge of pre-calculus. Based on the student's answers to previous questions, ALEKS selects the next set of questions a student must answer. Therefore, individual students see unique sets of assessment questions.

Upon completion of the initial knowledge check, ALEKS determines a student's knowledge state, which is depicted as a pie chart labeled "ALEKS Pie" (Figure 3.3). Each student will occupy different knowledge states or zone of proximal development (Vygotsky, 1960, 1986). For example, the yellow shown in Figure 3.3, depicts the Algebra and Geometry Review topics that have been learned/mastered from this

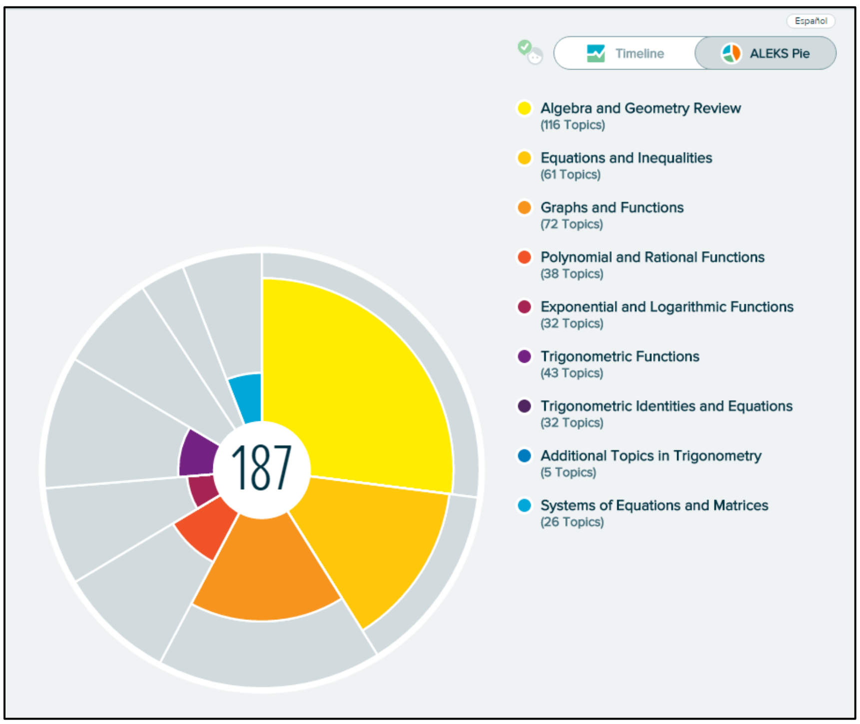


Figure 3.3. ALEKS Pie for online Pre-Calculus Course.

section. ALEKS constructs an individualized cognitive learning path consisting of course topics students follow to accomplish their objective goals. Students can continue on the learning path provided for them by ALEKS, or they can select another section from the ALEKS Pie and follow

a different learning path, so long as they have mastered all prerequisite topics for this new path. As students work on ALEKS, the program periodically reassesses the students' progress to confirm that topics continue to be mastered and that these topics remain in the students' long-term memory.

A midterm exam was given during the eighth week of each sixteen week semester, with a retake option one week later. The midterm exam grade was weighted 30% of a student's overall grade. A final exam was administered at the end of the semester and was 35% of the overall grade. Students were also provided with an option to retake the final exam two days after it was first administered. The highest scores a student earned on each exam were recorded in the student grade book. Course forum questions were posted weekly and were worth 5% of the total grade. Every semester an average of 20% of students drop prior to the end of the semester. The grade calculation for this class was as follows.

Review Topics	5%
Forum questions	5%
Prep for Midterm	10%
Midterm Exam	30%
Trigonometry	15%
Final Exam	35%

Students were required to spend a minimum of eight hours on ALEKS each week. Failure to maintain the time requirement for three consecutive weeks could result in a student being dropped from the course, as was stated in the syllabus. For this course, the week began on Monday at 12:01 AM and ended at 11:59 PM on Sunday. Students were responsible for keeping track of their weekly hours by clicking on the ALEKS menu bar, then clicking on their "Week's Activity" report. A tutorial explaining how to find the Week's Activity report was sent to each

student via email. Monitoring students' weekly hours and their progress on ALEKS was accomplished by utilizing and generating progress reports on ALEKS.

Progress Reports offered through ALEKS. A "Time-on-Topic Report" (Figure 3.4), was generated by the instructor and downloaded through the ALEKS reporting feature every Monday. This report allows the instructor to monitor students' time spent on ALEKS and to view the number of topics practiced and mastered each week. There are two sections of information in a Time-on-Topic Report; a graphical report, and a "time and topic" report for each student. Figure 3.4 depicts the graphical report of the average time, in minutes, that the entire class spent logged into ALEKS each day.

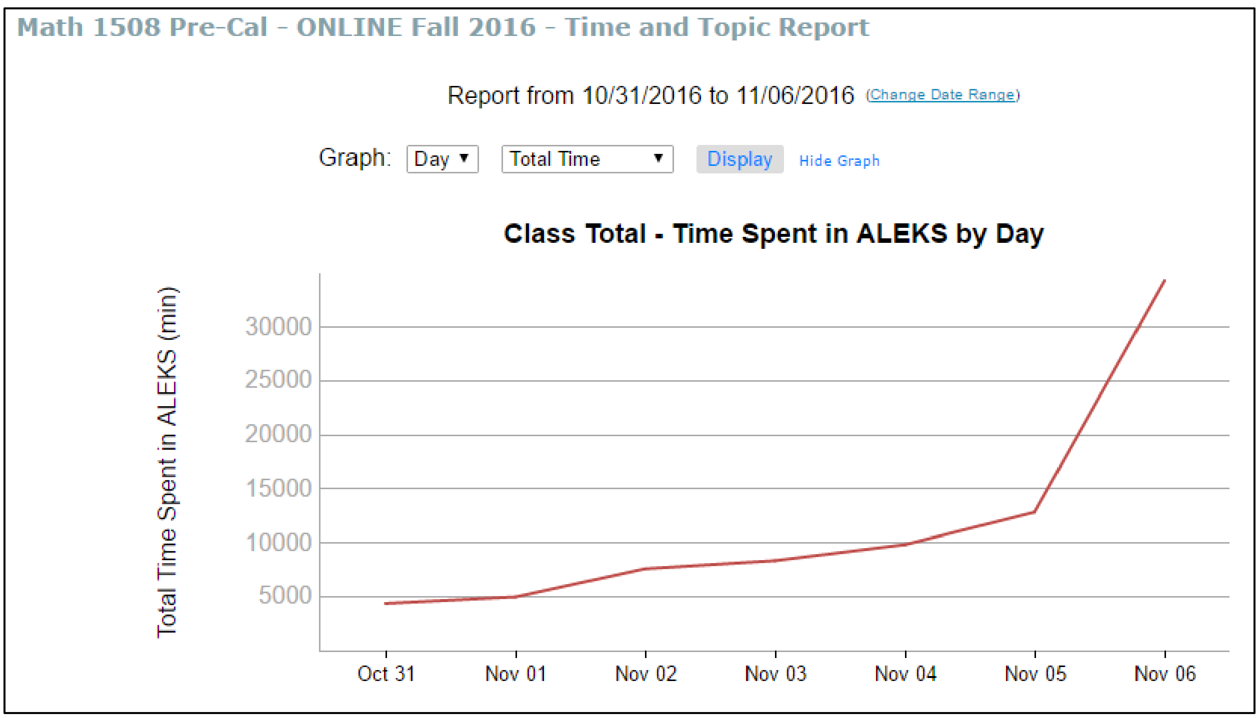
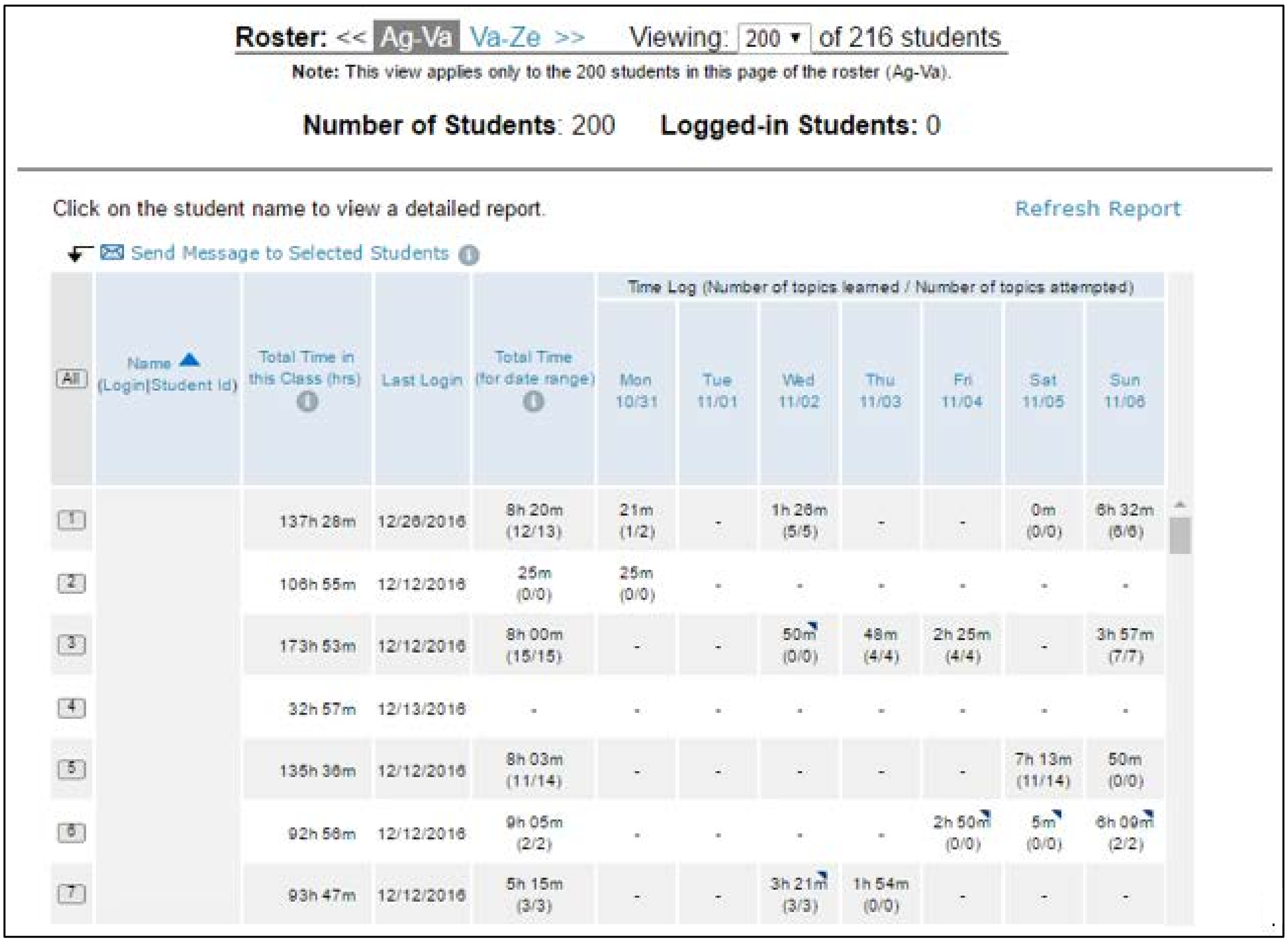


Figure 3.4. Example of a Time-on-Topic graphical report for the week beginning on Monday, October 31, 2016, and ending on Sunday, November 6, 2016.

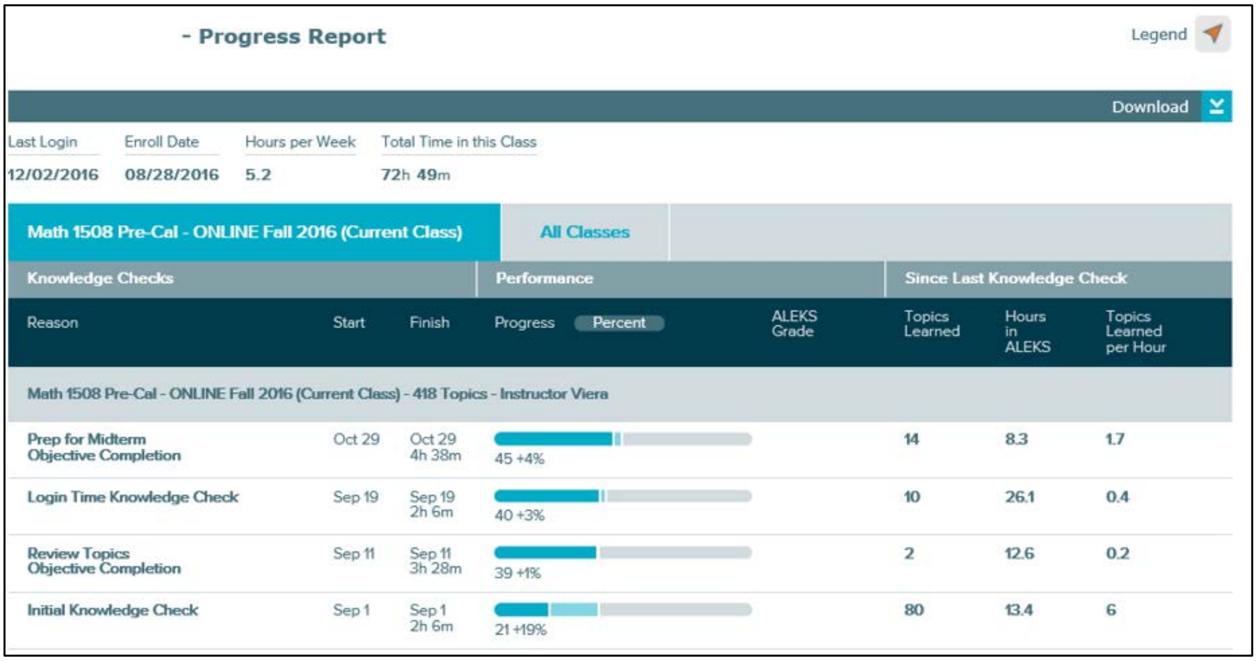
Figure 3.5 depicts the second Time-on-Topic Report, which displays a list of the students enrolled in the course along with their total time spent logged into the course, last login, total time for the week selected by the instructor (for date range), and the number of topics learned and practiced for each day of the week, beginning on Monday. This Time-on-Topic Report was converted into an excel file to keep track of student's weekly progress on ALEKS. Students who did not complete the mandatory eight hours for three consecutive weeks were sent an email informing them that they would be dropped from the course.



All	Name (Login|Student Id)	Total Time in this Class (hrs)	Last Login	Total Time (for date range)	Time Log (Number of topics learned / Number of topics attempted) Mon 10/31	Tue 11/01	Wed 11/02	Thu 11/03	Fri 11/04	Sat 11/05	Sun 11/06
1		137h 28m	12/28/2016	8h 20m (12/13)	21m (1/2)	-	1h 26m (5/5)	-	-	0m (0/0)	6h 32m (6/6)
2		106h 55m	12/12/2016	25m (0/0)	25m (0/0)	-	-	-	-	-	-
3		173h 53m	12/12/2016	8h 00m (15/15)	-	-	50m (0/0)	48m (4/4)	2h 25m (4/4)	-	3h 57m (7/7)
4		32h 57m	12/13/2016	-	-	-	-	-	-	-	-
5		135h 36m	12/12/2016	8h 03m (11/14)	-	-	-	-	-	7h 13m (11/14)	50m (0/0)
6		92h 56m	12/12/2016	9h 05m (2/2)	-	-	-	-	2h 50m (0/0)	5m (0/0)	6h 09m (2/2)
7		93h 47m	12/12/2016	5h 15m (3/3)	-	-	3h 21m (3/3)	1h 54m (0/0)	-	-	-

Figure 3.5. Example of Time-on-Topic list of student report for the week beginning on Monday, October 31, 2016, and ending on Sunday, November 6, 2016.

A “Learning Progress Report” is an ALEKS-generated a report that displays a student’s last login, their average hours per week, and their total time spent logged into in this class (Figure 3.6).



- Progress Report

Legend

Download

Last Login	Enroll Date	Hours per Week	Total Time in this Class
12/02/2016	08/28/2016	5.2	72h 49m

Math 1508 Pre-Cal - ONLINE Fall 2016 (Current Class) | All Classes

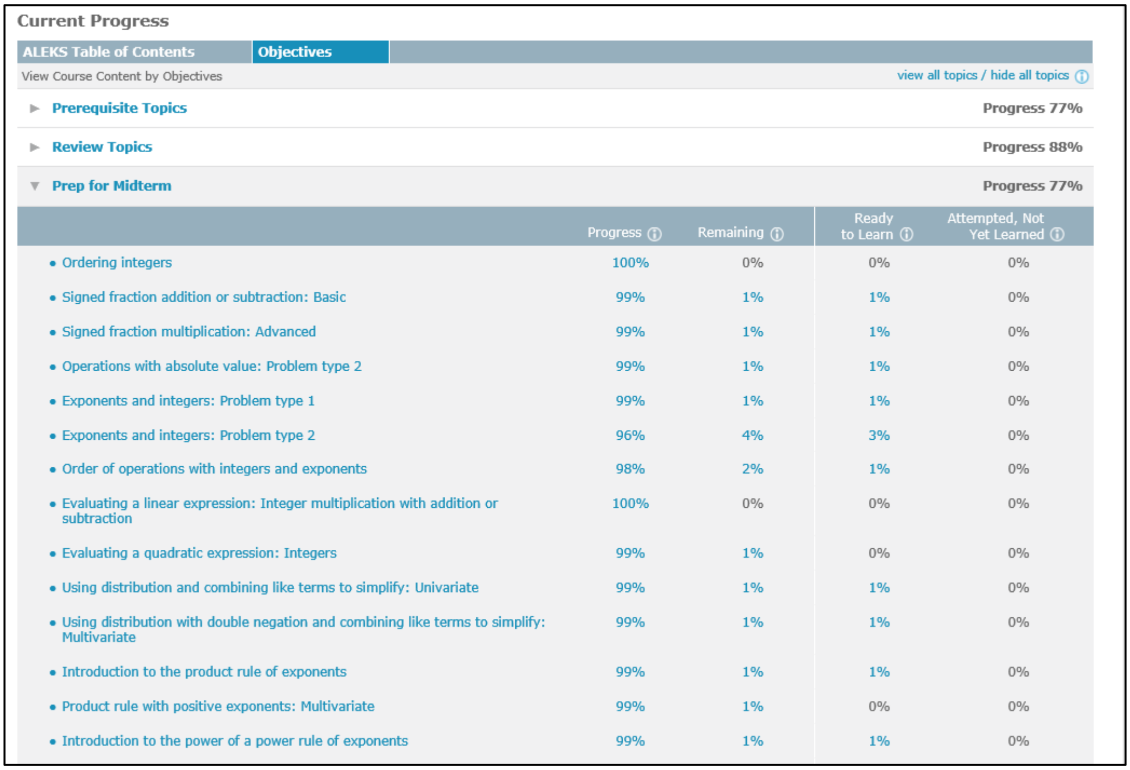
Knowledge Checks			Performance		Since Last Knowledge Check		
Reason	Start	Finish	Progress (Percent)	ALEKS Grade	Topics Learned	Hours in ALEKS	Topics Learned per Hour
Math 1508 Pre-Cal - ONLINE Fall 2016 (Current Class) - 418 Topics - Instructor Viera							
Prep for Midterm Objective Completion	Oct 29	Oct 29 4h 38m	45 +4%		14	8.3	1.7
Login Time Knowledge Check	Sep 19	Sep 19 2h 6m	40 +3%		10	26.1	0.4
Review Topics Objective Completion	Sep 11	Sep 11 3h 28m	39 +1%		2	12.6	0.2
Initial Knowledge Check	Sep 1	Sep 1 2h 6m	21 +19%		80	13.4	6

Figure 3.6. Example of Learning Progress Report for a fall 2016 student.

In the graph depicted in Figure 3.6, the darker shade of blue shows what percent the assigned number of topics a student has mastered, while the lighter blue shows percent of topics practiced. By clicking on the “percent” button, the percent display of the Learning Progress Report can also be converted into a bar graph that shows the raw number of topics mastered and practiced. Students can view their personal Learning Progress Report by clicking on Reports in the ALEKS menu bars. The instructor for this course utilized the Learning Progress Reports to monitor students’ progress with topics and to determine which topics students needed assistance with.

Figure 3.7 shows another report that ALEKS can produce. In Figure 3.7, an “ALEKS Pie Report” shows the percent of students who have mastered, not mastered, or are ready to learn the

topic listed on the left. This report is comprised of two sections: the ALEKS table of contents containing all of the topics for this pre-calculus course makes up one, and the Objectives section,



Current Progress

ALEKS Table of Contents | Objectives

View Course Content by Objectives — view all topics / hide all topics

► Prerequisite Topics	Progress 77%
► Review Topics	Progress 88%
▼ Prep for Midterm	Progress 77%

	Progress	Remaining	Ready to Learn	Attempted, Not Yet Learned
• Ordering integers	100%	0%	0%	0%
• Signed fraction addition or subtraction: Basic	99%	1%	1%	0%
• Signed fraction multiplication: Advanced	99%	1%	1%	0%
• Operations with absolute value: Problem type 2	99%	1%	1%	0%
• Exponents and integers: Problem type 1	99%	1%	1%	0%
• Exponents and integers: Problem type 2	96%	4%	3%	0%
• Order of operations with integers and exponents	98%	2%	1%	0%
• Evaluating a linear expression: Integer multiplication with addition or subtraction	100%	0%	0%	0%
• Evaluating a quadratic expression: Integers	99%	1%	0%	0%
• Using distribution and combining like terms to simplify: Univariate	99%	1%	1%	0%
• Using distribution with double negation and combining like terms to simplify: Multivariate	99%	1%	1%	0%
• Introduction to the product rule of exponents	99%	1%	1%	0%
• Product rule with positive exponents: Multivariate	99%	1%	0%	0%
• Introduction to the power of a power rule of exponents	99%	1%	1%	0%

Figure 3.7. Example of ALEKS PIE Report showing the list of topics for a Pre-calculus course.

separated into sub-sections by each of the three intermediary course objectives, makes up the other.

Each objective can be opened to show the percentage of topics completed and which topics the class as a whole is ready to learn. Another option is to click on the individual topics, labeled in Figure 3.7 at the left; this allows one to view the percent of students who have mastered that one topic and the percent of students who are ready to learn it. These reports were utilized to determine which topics the students were having difficulty with and whether a tutorial would be uploaded onto the ALEKS course forum.

Course Forum. The course forum is an ALEKS feature that resembles an online chat. The course forum feature on ALEKS must be authorized by the instructor at the beginning of the semester or when the course is created. The forum is a space in which the instructor can share files and communicate with students. Tutorials were posted on the course forum when requested by students and as determined by the Learning Progress Reports and ALEKS Pie Reports.

The course forum was utilized for this study to post questions about students' attitudes and opinions on the initial assessment, the midterm exam, and the amount of time spent on ALEKS. Forum questions were posted asking students about their online meaning making strategies (see Appendix J for a complete list of course forum questions). Confidentiality was of the highest importance, and as such, all forum responses were deleted from student view approximately one week after the questions had been posted.

Ethical Considerations

An Internal Review Board (IRB) proposal was submitted and approved prior to the beginning of the 2014 and 2015 fall semesters; the 2014 IRB was for a pilot study (see Appendices A and B). An IRB amendment was submitted in January 2016 and approved in February 2016 (see Appendix C), to extend the study into the 2016 spring and fall semesters and to include data and interviews from the fall 2014 pilot study and the fall 2015 semester. This consolidation of data from different semesters allowed for a more diverse and valid representation of emergent bilinguals' digital practices.

An email in both English and Spanish was sent to all students enrolled in the online pre-calculus courses containing a link to a digital consent form (see Appendix D) and demographic survey (see Appendix F), which were also both written in Spanish and English languages. Additionally, the email informed participants that the instructor would be functioning as the

researcher for this study. The email stated that their involvement in the study would have no bearing on their course grade. Both the email and the consent form stated that participants were permitted to end their involvement in the study at any time without repercussion.

The digital consent document was in both English and Spanish to ensure that students whom English is a second language understood the form. The consent form provided information about the structure of the study. It reiterated that participation in the study was strictly voluntary and that there were no consequences if a student declined to participate or withdrew from the study early. The consent form outlined what participation in the study would involve:

- You will be asked to complete a survey about your language and academic history in other math courses, as well as your online language behaviors in this course.
- You will be asked to answer weekly course forum questions in addition to your mandatory 8 hours spent on the online program.
- You will be asked to fill out one or two weekly logs describing your online language habits.
- You will also be asked to email the researcher screen shots of any online translation or tutorial videos that you use for this course.
- You may be selected to participate in an email interview.
- Your time spent on the online program and your weekly progress will be observed and recorded by the researcher.
- You will be asked to complete two self-efficacy surveys.
- Responses to surveys, forum questions will be collected by the researcher.

Confidentiality of student information was maintained by creating pseudonyms for participants. Data was coded and stored on a password-protected laptop computer accessible only to the researcher. Course forum questions and replies were the only sources of data that were visible to all students in the course. Each course forum question remained visible to the class for approximately one week. At the end of that week, all student replies and postings were

deleted from student view. Additional data collection was conducted through email interviews and face-to-face interviews with two key informants.

Review of Research Questions

The participants in this study were students who enrolled in one online pre-calculus course over four semesters. The focus of this study was to open a window of understanding into participant's digital practices in an increasingly technological academic world. Two self-efficacy surveys were distributed during the 2016 spring and fall semesters to understand if translating the ALEKS software affected participant's self-efficacy and measure the confidence of the participants with regards to mathematics and technology. The demographic survey, pre- and post-surveys on self-efficacy, course forum questions, email interviews, and weekly student logs with screenshots, were utilized to answer the following research questions.

Qualitative Research Questions:

3. How do undergraduate emergent bilinguals 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?

Quantitative Research Question:

4. Do digital meaning making practices such as email, course forums, texting, translating software, and online videos impact self-efficacy?

Design of Methodology

A mixed methods design through an Activity Theory lens was selected for this study in order to explore how emergent bilinguals engage in a fully online pre-calculus course.

Qualitative data was examined through content analysis and constant comparison methods to discover how emergent bilinguals utilize their mathematical academic language and digital practices to make meaning of an online pre-calculus course. Quantitative data was analyzed to support the findings of the qualitative data as well as to find an association between emergent bilinguals' digital practices and students' self-efficacy, measured through two pre- and post-self-efficacy surveys.

Further, this study followed an embedded-exploratory design; Figure 3.8 depicts the four phases utilized in this design. The purpose was to take advantage of the combination of two designs: an embedded design, where qualitative and quantitative data collection and analysis occur in parallel; and an exploratory sequential design in which findings are revealed through analysis of qualitative data (Creswell & Clark, 2007).

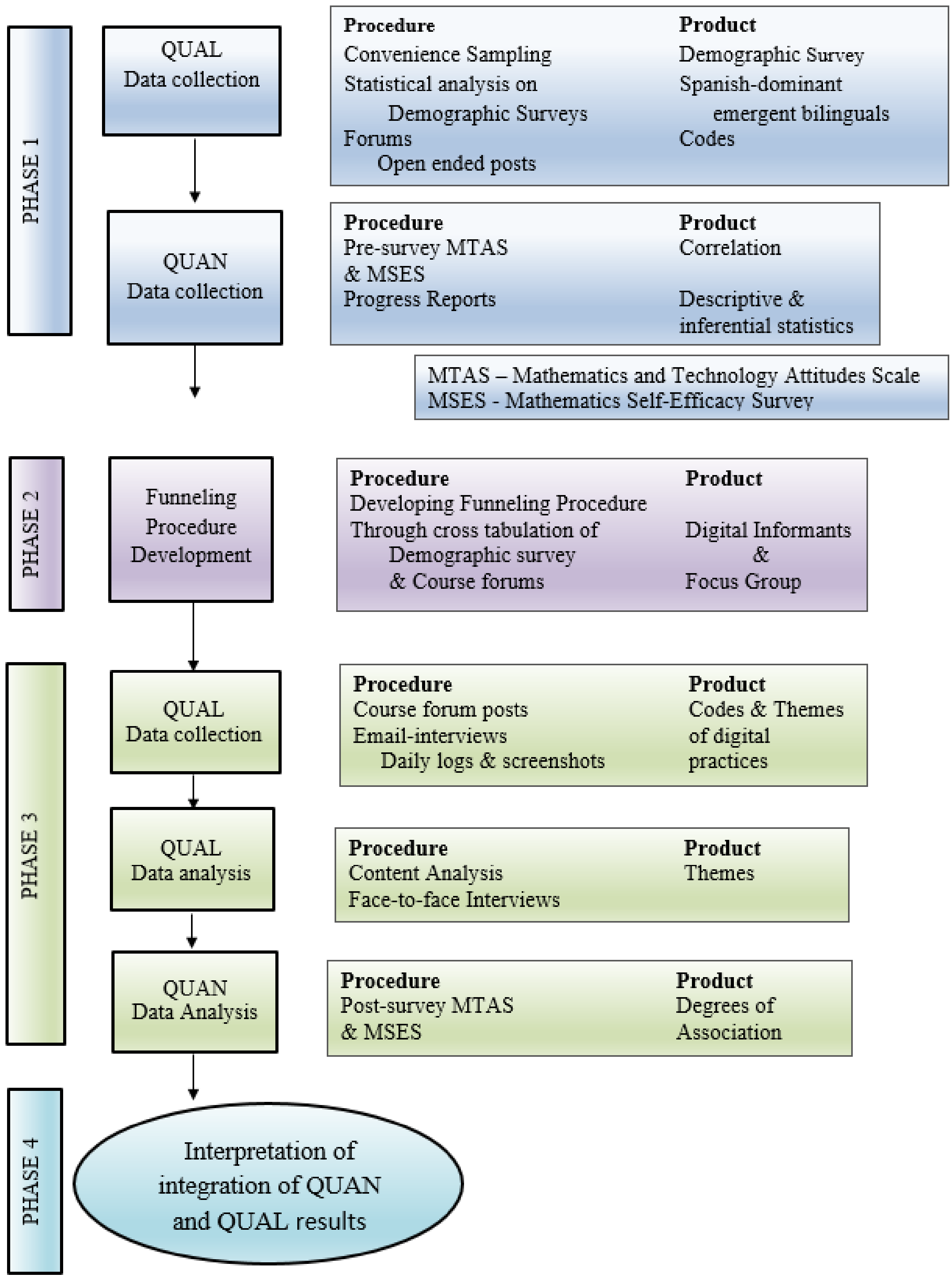


Figure 3.8. Embedded-exploratory design for the described study (Creswell & Clark, 2007).

In this study, both qualitative data and quantitative data were analyzed for the dual purposes of discovering emergent theories and finding an association between translating ALEKS and self-efficacy for math and technology. Thus, the embedded-exploratory design was the best fit for the study.

Qualitative and quantitative data was rigorously collected and analyzed throughout the course of the study. Qualitative data from this study allowed for an opportunity to understand the human experiences of participants in an online mathematics course (Lichtman, 2012). Quantitative data that supported the qualitative themes, Time-on-topics reports, Learning Progress Report, and ALEKS Pie Report was collected each week. These reports were analyzed to provide an extensive picture of participants' experiences and responses to course forum questions, and email interviews. Pre-surveys on self-efficacy were completed during the second week of the 2016 spring and fall semesters and post-surveys on self-efficacy were completed during the final weeks of the semester.

Mixed methods: Embedded-exploratory design. Built on a constructivist paradigm the research approach utilized in this study was an embedded-exploratory design (Creswell & Clark, 2007; Lichtman, 2006). Several studies have employed a modified embedded design to test the effectiveness of an online intelligent tutoring system (Canfield, 2001; Xu et al., 2009). In these studies, quantitative data analyses of pre- and post-tests were used to determine if an intelligent tutoring system was effective in increasing understanding of mathematical concepts and class grades. These findings were supported by the findings of the qualitative open-ended surveys.

Another variant is an embedded-explanatory design identified by the embedding of qualitative data within an experimental quantitative design (Creswell & Clark, 2007). In a traditional embedded design, the primary data can be collected and analyzed before, during or

after the supplementary data. Then the supplementary data is used to support the primary findings (Creswell & Clark, 2007). In this dissertation study, the data collection and analysis for both qualitative and quantitative occur simultaneously.

The exploratory design aspect of the present study identified developing theories on how emergent bilinguals engage in an online mathematics course utilizing digital practices. Research on how emerging bilinguals engage in an online mathematics course and how their self-efficacy is affected, if at all, is uncommon. The combination of an embedded design with an exploratory design allowed for the simultaneous use of both quantitative and qualitative methods to provide data while themes and theories were allowed to emerge. A mixed methods design was best suited for this study.

History of previous pilot studies. Two pilot studies were conducted in relation to this dissertation, both of which greatly influenced the direction of this research study. The first pilot study was conducted in the summer of 2013. This pilot study researched the effectiveness of the software, ALEKS, in improving the college math placement of a group of high school rising seniors. Rising seniors is a term for students during summer break between their junior and senior year of high school. This pilot study found that emergent bilinguals from this group preferred to keep the ALEKS software in English as opposed to translating it into their native language.

The second pilot study, conducted in the fall 2014 semester in a fully online college-level pre-calculus course, provided evidence that students digital activities were a complex sociocultural endeavor. Spanish-dominant emerging bilinguals, mediated the translation capabilities of the ALEKS software and online translators to make meaning of English vocabulary and mathematical terminology. A brief description of each study follows.

Summer bridge pilot study. During the summer of 2013 and working with my advisors, I submitted an Internal Review Board proposal to examine the effectiveness of an intelligent tutoring system in increasing college readiness for rising seniors. Participants were recruited from an eight-week summer bridge program at the University of Texas at El Paso. This summer bridge program was designed to help Spanish-dominant emergent bilinguals improve their math college placement as determined by the Texas Higher Education Assessment (THEA). Participants had first taken the THEA their junior year.

With the guidance of my advisors, I designed consent and assent forms, focus group questions, and interview protocols that were conducted during the summer bridge program. The proposal was submitted and approved by the university Institutional Review Board. A proposal was also submitted to and approved by the Institutional Review Board at the Ysleta Independent School District, where the students were enrolled. After receiving Institutional Review Board approval, from both the university and school district, recruitment of participants began with an announcement during the first day of the summer bridge program. Consent and assent forms, written in both English and Spanish, were provided to students.

This pilot study utilized an intelligent tutoring system named ALEKS as the intervention instrument to measure its effectiveness at increasing these emergent bilinguals' college math placement. The pilot study found that students who utilized ALEKS in a remedial Algebra course showed a statistically significant improvement on their college math placement. The THEA test was the assessment employed to measure each student's improvement and overall college readiness. Participants took the THEA test during the first and last week of the program. A one-sample t-test was performed and found the intervention, using ALEKS in an Algebra

class, to be statistically significant ($t = 25.58;\ p < 0.05$) in increasing post-test results. Thus ALEKS appeared to increase participants' college math placement.

During face-to-face interviews, one of the participants was asked if she changed ALEKS into Spanish. She stated that she did not. When asked which language she preferred to engage with the software, she stated: "en inglés, por los exámenes…porque hay palabras en Inglés que no sé qué son en español pero si sé que es Inglés." [in English, because of the exams…because there are some words in English that I don't know what they are in Spanish but I do know them in English.] She felt that changing the software into English would be an obstacle when she took the THEA test. This finding was of particular interest because she was one of the students who improved her pre-test post-test results without translating the software into Spanish.

The reluctance of this participant to change the software into Spanish dispelled my assumption that emergent bilinguals would translate the software given the opportunity to do so. It also provided a glimpse into Spanish-dominant emerging bilinguals' attitudes about learning English, in particular how they felt it was important to learn English even while working on software that could be translated. This insight led me to focus my studies on using ethnographic approaches to investigate how emergent bilingual students engaged with an intelligent tutoring system.

Fall 2014 pilot study. During the 2014 fall semester, I wrote a second pilot study proposal with support from my dissertation chair and Qualitative II professor. This pilot study provided the opportunity to investigate students' language use in an online pre-calculus course utilizing an intelligent tutoring system. A proposal with consent forms, course forum questions, and email interview questions was submitted and approved by the university Institutional Review Board in May 2014.

Of the 242 students enrolled for an online pre-calculus course, 134 electronically signed the consent form and began the initial demographic survey. Two students were removed as participants because they did not sign the online consent form correctly and 132 students completed the survey. Sixty-three participants responded to the course forum questions. Of these 63 participants 10 participants, said they translate math problems in their mind “all of the time.” These 10 participants were selected to be in a focus group labeled Study Group #1, while the remaining 53 participants were assembled into a focus group labeled Study Group #2. Participants in both groups were asked to respond to course forum questions, and their replies were collected and recorded onto an excel file for content analysis.

The course forum questions and interviews were collected and analyzed using virtual ethnography or cyberethnographic methods. Three themes emerged from the data; thinking in Spanish for basic mathematical concepts, converting ALEKS into Spanish and the importance of keeping the software in English. Participants were intent on learning topics in English because they felt that future topics and classes would be taught in English and they wanted to make cognitive connections between pre-requisite topics with future topics in the same language.

The themes that emerged from these two pilot studies supported the value of pursuing a formal study on this topic. To this end, I refined the demographic survey, course forum questions, and email interviews. I added a student daily log with screen shots, which participants would send to the researcher via email. Finally, two self-efficacy surveys were added for the 2016 spring and fall semesters for the purpose of finding an association between students’ digital practices and their self-efficacy towards mathematics and technology. Thus, this dissertation study is an extension of these two pilot studies.

Sampling Procedures Used in Dissertation Research

A recruitment email was sent to all students registered for the online pre-calculus course recruiting. A total of 887 students were enrolled in these classes, 251 students from fall 2014, 235 in fall 2015, 166 in spring 2016, and 235 in fall 2016. The email contained a brief description of the study and a web link to the digital consent form and demographic survey. In the 2016 spring and fall semesters, two self-efficacy surveys were added to the quantitative data collection. Historically, this online math class was comprised of 37% males and 62% females.

Analysis of the course forum posts and the demographic surveys provided a unique sampling procedure. Through a funneling process or sequential mixed methods sampling technique, students enrolled in the online pre-calculus courses were funneled into smaller groups of interest. These groups were first determined by those who signed consent forms and completed the demographic survey (Figure 3.9).

Table 3.1 depicts the cross tabulation results calculated for the fall 2015 semester, the cross tabulations for all four semesters can be found in Appendix R through U. The total number of responses along with totals for each question are highlighted in gray. The light-green highlighted cells identified those students who responded ‘Quite often’ or ‘Very Often’ to the questions in the left column. The dark-green highlighted cells were used to represent meaningful

Table 3.1.

Fall 2015 cross tabulation of demographic survey.

		What language do you speak most often at school?				
		English	**Spanish**	**Both**	**Other**	Total
How often do you use the internet to translate words you do not know the meaning to?	**Never**	17	0	1	0	18
	Rarely	28	0	5	0	33
	Sometimes	33	0	8	0	41
	Quite Often	**8**	0	1	0	9
	Very Often	4	0	1	0	5
	Total	90	0	16	0	106
How often do you think in Spanish when you work on math problems?	**Never**	63	0	4	0	67
	Rarely	21	0	4	0	25
	Sometimes	4	0	5	0	9

	Quite Often	2	0	2	0	4
	Very Often	0	0	1	0	1
	Total	90	0	16	0	106
How often do your translate math homework in your mind in order to understand the assignment?	**Never**	58	0	5	0	63
	Rarely	15	0	7	0	22
	Sometimes	6	0	2	0	8
	Quite Often	9	0	1	0	10
	Very Often	2	0	1	0	3
	Total	90	0	16	0	106

		What language do you speak most often at home?				
		English	**Spanish**	**Both**	**Other**	Total
How often do you use the internet to translate words you do not know the meaning to?	**Never**	12	1	5	0	18
	Rarely	14	9	10	1	34
	Sometimes	23	10	6	2	41
	Quite Often	4	2	3	0	9
	Very Often	3	0	1	1	5
	Total	56	22	25	4	107
How often do you think in Spanish when you work on math problems?	**Never**	50	1	13	4	68
	Rarely	5	9	11	0	25
	Sometimes	1	7	1	0	9
	Quite Often	0	**4**	0	0	4
	Very Often	0	1	0	0	1
	Total	56	22	25	4	107
How often do your translate math homework in your mind in order to understand the assignment?	**Never**	43	7	14	0	64
	Rarely	4	10	7	1	22
	Sometimes	3	3	1	1	8
	Quite Often	4	2	2	2	10
	Very Often	2	0	1	0	3
	Total	56	22	25	4	107

associations to identify participants as Spanish-dominant emergent bilinguals. For example, Table 3.1 demonstrations that eight participants, dark-green highlight, reported that they frequently speak English in school and that they use the internet to translate words they do not know ‘quite often.’ Also shown in Table 3.1 are four participants, light-green highlight, who reported that they speak Spanish at home most often and also think in Spanish when performing mathematical calculations. These cross tabulation associations were utilized to identify the focus group of Spanish-dominant emergent bilinguals.

Thirty-five students were identified as Spanish-dominant emergent bilinguals through this analysis, see F2 in Figure 3.9. Through constant comparisons and content analysis of the course forums, a focus group of Spanish-dominant emergent bilinguals was identified in each of the four semesters with 7 to 10 participants (see F3 in Figure 3.9). These Spanish-dominant emergent bilinguals were sent email interview questions to induce deeper insights into their course forum posts. Participants in this study were continually funneled into smaller focus groups in order to collect in-depth lived experiences of their digital practices and language use in this fully online mathematics course.

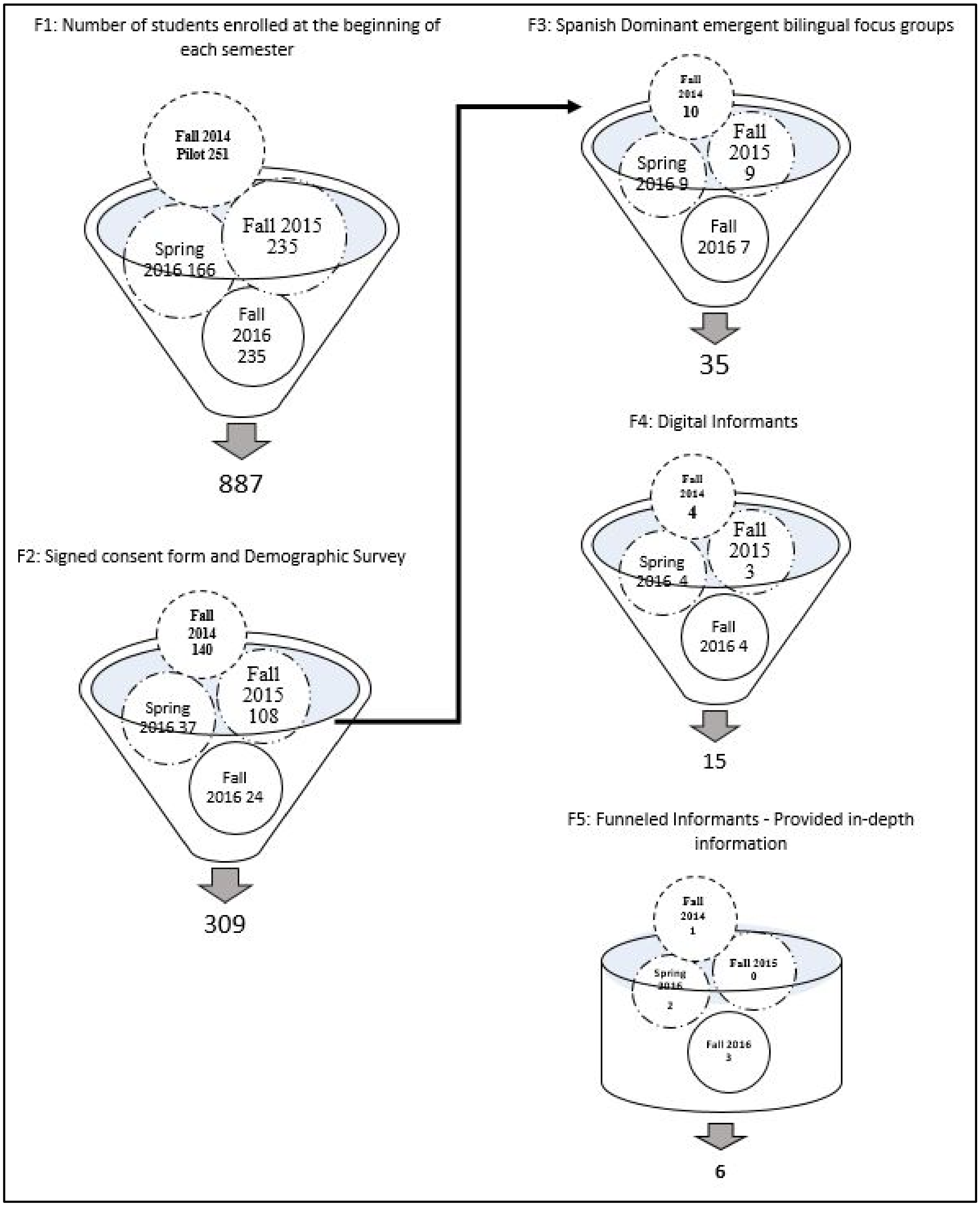


Figure 3.9. Diagram of funneling procedure. The number of participants was reduced through a series of filters: consent forms, demographic survey, digital information, in-depth information.

In Figure 3.9, F4 depicts those Spanish-dominant participants from the focus groups who provided in-depth information about their digital experiences in this course. These participants were identified for this study as “Digital informants” due to the fact that they responded to all forms of digital inquiries. The term “Funneled informants” was coined to identify the six participants who provided rich, in-depth information about their digital practices for meaning making (see F5 in Figure 3.9). A detailed numerical tabulation of the students enrolled in these online pre-calculus courses which were funneled into successively smaller participant groups is shown in Table 3.2.

Table 3.2.

The funneling stages and categorical n of students enrolled in an online pre-calculus course

	Number of Students Enrolled at the start of semester	Number of students which completed course	Number of students who signed consent form	Cross Tabulation to identify Spanish-dominant Emergent Bilinguals	Digital informants - number of participants who provided email responses	Funneled informants - number of participants who provided in-depth copious amounts of data
Fall 2014	251	201	140	10	4	1
Fall 2015	235	214	108	9	3	0
Spring 2016	166	142	37	9	4	2
Fall 2016	235	217	24	7	4	3
Totals	887	774	309	35	15	6

Overview of Data Collection

Data was gathered from one demographic survey, two self-efficacy surveys, eight to ten weekly course forum questions, daily logs with screen shots, email interviews with focus groups, and face-to-face interviews with six key informants to understand the digital practices of emergent bilinguals participating in an online pre-calculus course. The unit of analysis for this study was the activity system created to diagram emergent bilinguals’ meditated actions for meaning making. Data analysis in an embedded design requires that qualitative data will be analyzed before, during and after the supplementary quantitative data has been analyzed. In this embedded-exploratory study, four themes emerged from the data: the importance of learning

English; translating software to Spanish and using online translators; meaning making; Students creating a bilingual digital learning environment.

Course Data. The quantitative data from the Time-on-Topic Report, Learning Progress Report, and ALEKS Pie Reports were generated through the ALEKS software. These reports were created by the instructor and can focus on specific criteria. Time-on-Topic reports can be created by days, weeks, months or semester, for one student or a group of students. Similarly, Learning Progress Report and ALEKS Pie Reports can be produced with detailed information about the topics practiced and mastered. Course forum open-ended questions were posted weekly, beginning on the third week of the semester in phase one of the study. Every student had access to and the opportunity to answer the course forum questions. Credit was given for simply answering the forum questions. The content of the replies was not graded.

Data Collection Plan.

Phase one. Students who signed the consent forms completed a demographic survey with questions about educational history, language practices at home and in school and degrees of self-efficacy. The demographic survey was coded to identify Spanish-dominant emergent bilinguals. Through convenience sampling and a cross tabulation students who were identified as Spanish-dominant emergent bilinguals were placed into a focus group of approximately 9 to 10 participants.

Two self-efficacy surveys were created for the 2016 spring and fall semesters. Participants completed two pre-surveys during phase one of the study: the Mathematics and Technology Attitudes Scale (MTAS) and The Mathematics Self-Efficacy Survey (MSES). The MTAS was a 5-point Likert scale survey comprised of 27 items measuring confidence and attitudes about mathematics and technology (Pierce et al., 2007). The MSES assessed a student's

confidence in everyday mathematical problems and math-based college courses (Betz & Hackett, 1983). The MSES survey contains 34 items measured on a 5-point Likert scale. Thirty-four of the participants who signed consent forms completed the MTAS pre- and post-surveys, while 36 completed the MSES pre- and post-surveys. Self-efficacy post-surveys were completed by participants in phase three and analysis for an association between participants' self-efficacy and digital practices was completed during phase four.

Phase two. Open-ended course forum questions began after the second week of the semester. All students registered for the pre-calculus course were asked to answer the forum questions. In the course forum, participants were asked if they change the software to Spanish. More specifically, they were asked if they change the midterm exam to Spanish. Table 3.3 shows three course forum question posted by the instructor/researcher and the responses of three

Table 3.3.

Example of course forum posts.

	How did you feel about your initial assessment in the program ALEKS?	**If you changed the ALEKS program into Spanish, explain how this affected your understanding of the topics.**	**Did you change the midterm to Spanish?**
Participant 1	This initial assessment was a little bit long and challenging but Math are coming back to my brain. It is like a language that if you don't practice you will forget about it. Support videos found in YouTube helped me so I could refresh myself in Algebra. I find ALEKS Learning Program pretty professional and dynamic. I still do not get used to the mandatory 8 hours a week rule. Last week I got everything done before the due date and still received the class drop warning from you, but now I am understanding how that rule works.	I change it when I don't know the meaning of a word or concept because all my previous algebra and math knowledge is in Spanish, but I try to keep it up in English.	I do changed the language setting to Spanish in two questions just to make sure I was understanding concepts correct. My first language is Spanish.
Participant 2	ALEKS is a great program for students whose greatest suit may not be math. The fact that you get to work at your own pace and understanding really ensures that you're prepared for your next math course.	I have not change the language but since Spanish is my first language it's nice to have the option in case I don't understand something	I did not change the midterm exam Spanish
Participant 3			En algunas preguntas si lo cambie …solo lo cambien a español en algunas preguntas

participants. Through content analysis of forum questions, Digital informants were identified and sent email questions to discuss their forum posts in depth.

Phase three. In phase three, posting of course forum questions and responses continued and were collected; mean-while, email interviews were initiated. Participants were reminded that participation in this study would in no way impact their course grade. The email interviews attempted to have participants elaborate on their forum posts. Key informants identified through analysis of the email interviews were sent a daily logs template to be filled out and sent back to the researcher. The daily log was an Excel file table asking students to report the time they logged into ALEKS, the time they logged out, how many times they translated the software, and how many times they clicked on the explain button (See Appendix M). Along with the weekly logs, participants were asked to take screen shots of their digital activities and send these artifacts to the researchers. Through content analysis and constant comparison methods, six key informants were identified to participate in focused email interviews and face-to-face interviews. Through the funneling process describe above the sample of participants was narrowed down from several hundred to a focus group of about 9 or 10, and finally to 6 key informants.

During phase three, which took place in the 2016 spring semester participants completed the two self-efficacy post-surveys. The surveys were administered during the fourteenth week of a sixteen week semester. A two-way multivariate analysis of variance (two-way MANOVA) was conducted on both the MTAS and MSES pre- and post-surveys (N=13) with the two independent variables being a student's self-efficacy and whether a student translated the software or not.

Phase four: Data analysis plan. Utilizing content analysis, course forum posts and email interviews were coded and categorized into initial codes, followed by focused codes (Lichtman,

2012). Through a constant-comparative method and the use of open and selective coding, the course forum posts, emails interviews, and daily logs were analyzed through the use of open coding and selective coding to relate initial codes together and discover emerging themes (Lichtman, 2012). The quantitative data was visually inspected prior to analysis, to ensure the validity of the data. Descriptive statistical analysis of the quantitative data was used to support the qualitative data analysis. Descriptive statistical analysis was conducted and checked for trends and distributions (Creswell & Clark, 2007; Teddlie & Tashakkori, 2012). Finally, the analysis of the data was used to answer the research questions.

The first survey, MSES, measured a participant's self-efficacy in mathematics (Betz & Hackett, 1983) and the second survey, MTAS measured their confidence in doing mathematics and working with technology in a mathematics course (Pierce et al., 2007). Four of the 35 Spanish-dominant participants completed the MTAS survey, and another four completed the MSES survey. Two of these participants, Rosario and Susi, completed both surveys. Statistical analysis of both surveys did not show statistical significant interaction between self-efficacy with mathematics and technology and whether a student translated the software or not

Issues of Trustworthiness

Guba (1981) developed four criteria for trustworthiness: credibility, transferability, dependability and confirmability. Each criterion was taken into consideration when developing trustworthiness for this study. Mixed methods is a recognized and credible research approach with two proven research designs: embedded and exploratory designs. For this study, both an embedded and an exploratory (Creswell & Clark, 2012) designs were morphed into a new archetype. The positionality of the researcher/instructor was clearly indicated to participants to ensure honesty during iterative questioning in the data collection. Member checks were

conducted on rich and robust qualitative data; for dependability, this data was coded and analyzed for categories and themes (Shenton, 2004). Confirmability was determined through triangulation of the course forum posts, email interviews, and face-to-face interviews. A comprehensive and thorough literature review was conducted to position this research with current studies and establish the context for this research's transferability.

Study Timeline

Pilot Studies	Summer 2013 (pilot study 1); Fall 2014 (pilot study 2)
July 2015	Submitted IRB proposal with required documents
Aug. 2015	Received IRB approval
Sept. 2015	Recruitment of students enrolled in Math 1508 Pre-Calculus via email
Sept. 2015	Consent forms and Survey recorded
Oct. 2015	First Course forum question posted
Fall 2015	Analysis of course forum posts
Nov. 2015	Begin email interviews with focus group
Nov. 2015	daily logs and screenshots collected
Jan 2016	Submit amendment to IRB proposal to extend study into spring semester
Jan 2016	Received IRB approval for amendment
Jan 2016	Recruitment of students enrolled in Math 1508 Pre-Calculus via email
Feb 2016	Consent forms and Survey recorded
Feb 2016	First Course forum question posted
Apr. 2016	Analysis of course forum posts
Apr 2016	Begin email interviews with focus group
Apr 2016	Daily logs and screenshots collected

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Fall 2016	Analysis of course forum posts
Nov. 2016	Begin email interviews with focus group
Nov. 2016	daily logs and screenshots collected
Fall 2017	Continuous data analysis
Apr. 2017	Findings written and reported
Apr. 2017	Communicate with Dissertation Committee
Apr. 2017	Defend Dissertation

Summary of Chapter 3

This chapter offered a comprehensive description of the research methodology utilized in this study. A mixed methods embedded-exploratory design was employed to explore the digital practices emerging bilinguals utilized to engage in an online pre-calculus college course taken at the University of Texas at El Paso. As well as presenting the setting of the study and its design and sampling procedures, this chapter described the ethical considerations for this dissertation. The procedures used to collect and analyze qualitative and quantitative data were also explained.

Limitations of the methodology employed in this study should be considered. Data collected for qualitative analysis was self-reported limiting this study's generalizability. This study focused on one intelligent tutoring system, ALEKS making it difficult to replicate in another online mathematics course.

A purposeful sampling through a funneling process was conducted from students enrolled in an online math course and key informants were identified through three data collection

methods: 1) a demographic initial survey; 2) course forum questions; and 3) weekly logs. Credibility and validity were ensured by utilizing member checking and triangulation of the data. Chapter 4 provides an explanation of the complex digital environment in which emergent bilinguals were engaged while participating in a fully online pre-calculus course. This explication is provided in the context of activity systems. The analysis of the data will be presented in Chapter 5; lastly, findings, conclusions and possible implications and recommendations are presented in Chapter 6.

Chapter 4

Activity Systems Context and Supporting Findings

Overview

This chapter summarizes and identifies each component of the three activity systems developed to explain emergent bilinguals digital practices for meaning making and mathematical understanding. The six components are the: (1) subject, (2) object and goal, (3) rules, (4) community, (5) division of labor (roles), and (6) mediated artifacts/tools. The qualitative findings detailed in this chapter support the definitions of each component within each activity system.

Activity systems analysis is a methodology that provides a systematic approach to understanding learners activities and interactions in real-world complex learning environments (Yamagata-Lynch, 2010a, 2010b), such as an online mathematics course. This method of analysis is designed to enhance the understanding of learners' activity situated in a collective context (Engeström, et al., 1999; Kaptelinin, & Nardi, 2012). The tenets of Activity Theory were presented in chapter 1. The three activities of interest in the present study were emergent bilinguals' use of (1) the translation capabilities in the ALEKS software, (2) online translators, and (3) culturally relevant videos. In order to fully understand emergent bilinguals' use of these digital resources, a thorough examination of their course and online environment is necessary. There were a number of interacting factors that influenced emerging bilinguals' digital practices in meaning making of English vocabulary and mathematical lexicon. Therefore, this chapter presents three activity diagrams to explain these digital practices.

An activity system model is represented by a triangular diagram (Figures 4.1, 4.2, and 4.3). This diagram was modified from the activity system developed by Engeström et al. (1999). The first diagram, Activity System 1 (AS1) (Figure 4.1), depicts the activity of translating the

course software. ALEKS was the software utilized by participants in this fully online pre-calculus class. A second activity triangle, Activity System 2 (AS2) (Figure 4.2), diagrams how online translators were mediated by participants for the online pre-calculus course. These first two activity systems represent the digital practices of emergent bilinguals for meaning making of English vocabulary and mathematical lexicon within the ALEKS software as well as externally. The third diagram describing Activity System 3 (AS3), (Figure 4.3), depicts how culturally relevant videos were mediated to make meaning of mathematical lexicon to further participants' understanding of the mathematics.

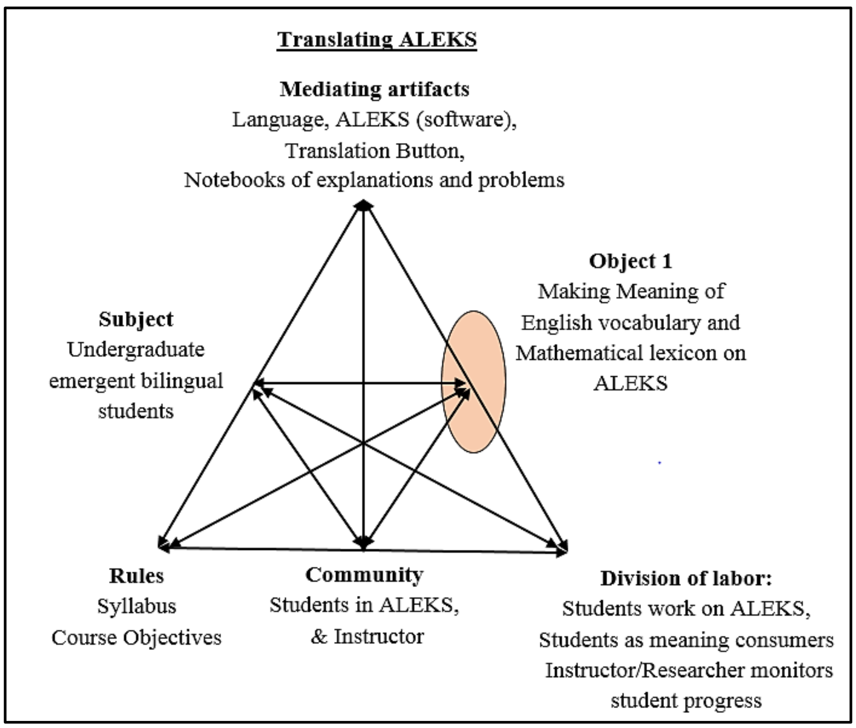


Figure 4.1. Activity System 1 for translating ALEKS.

Subjects

The subjects, depicted in AS1 (Figure 4.1), AS2 (Figure 4.2), and AS3 (Figure 4.3), were undergraduate emergent bilingual participants who were funneled into focus groups of Spanish-dominant Digital informants. Digital informants were those participants who provided in-depth

information through all digital communications, such as course forums and email correspondences. Funneled informants were selected from the Digital informants for face-to-face interviews based on the information they provided in the email correspondences. All participants were recruited from students who enrolled in a fully online, one-semester pre-calculus class offered during four semesters at a United States university on the U.S.-Mexico border. A total of 887 students enrolled in these classes at the beginning of each semester, 251 in fall of 2014, 235 in fall of 2015, 166 in spring 2016, and 235 in fall 2016. Thirty-six Spanish-dominant emergent bilinguals were identified through a cross-tabulation of responses to several demographic survey questions pertaining to language use at home and school.

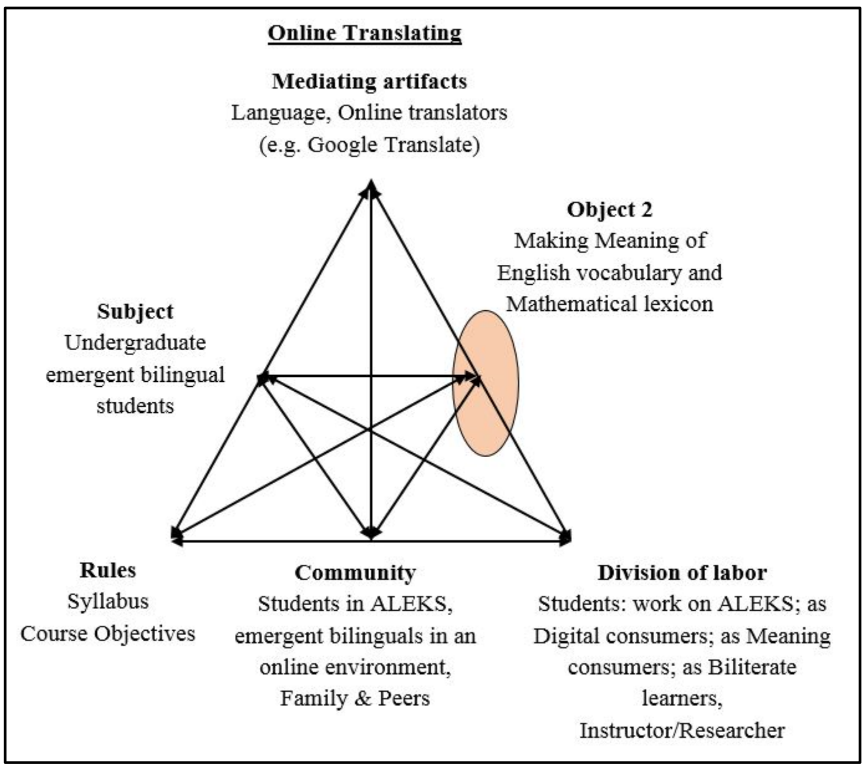


Figure 4.2. Activity System 2 for the use of online Translators.

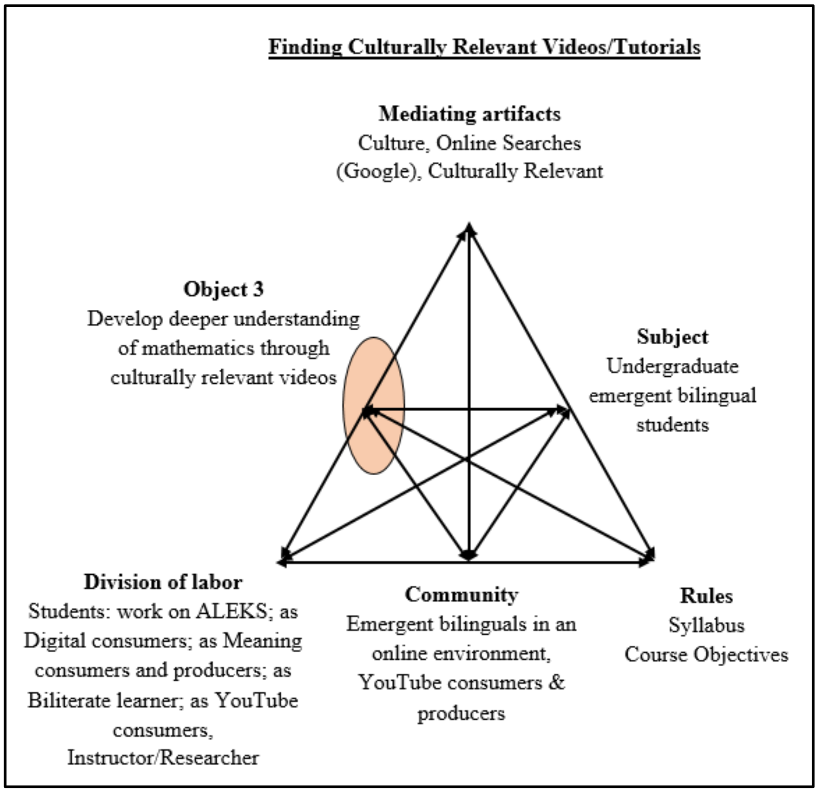


Figure 4.3. Activity System 3 for finding culturally relevant videos and tutorials.

Participants who were identified as Spanish-dominant emergent bilinguals were students who were primarily educated in Mexico. Forty-six percent of these participants attained their high school diplomas from Mexican high schools. Participants who provided insight into their digital practices and experiences were Marco, Carmen, Keith, Gracia, Laura, Fernando, Anna, and Alvaro (pseudonyms of original names). Keith and Marco stated that the language of instruction for all their mathematics classes was Spanish until they reached Algebra, which was taught in English. Participants who left Mexico to continue their education in the United States, such as Laura, Oscar, Susi, Esmeralda, and Ray, left between the fifth and eighth grade. These participants were enrolled in bilingual as well as English monolingual mathematics classes.

The Digital informants reported that they learned basic arithmetic in Spanish while attending elementary school in Mexico. Those participants who moved to the United States after middle school were placed into bilingual courses where they learned Algebra predominantly in English. They then transitioned into monolingual mathematics courses. Those participants who continued their education in Mexico learned Algebra in Spanish-English bilingual classes or English monolingual classes. Hence, many of the participants stated that when they performed basic arithmetic in their minds, they did these mental operations in Spanish. However, when the mathematics was of a conceptual nature, such as Algebra, participants thought about these in English. Carmen attempted to articulate how both English and Spanish played into her mathematical thought processes:

> I always think in English while reading the problems, yet because I was in school up until high school in Mexico, I do most of the math procedures in my head saying the numbers in Spanish, yet all the concepts in English. I don't know if that made sense, for example, I don't know the word for slope in Spanish, so I make reference to this concept thinking in English, but when I'm doing the simple math, I think about the numbers in Spanish.

Emergent bilinguals' cognitive connections to arithmetic and Algebra are developed through their language of instruction (Moschkovich, 2007). Moschkovich (2007) found that emergent bilinguals come to an awareness that their bilingualism could be used as an asset for their understanding of mathematics. In this study, one Digital informant, Laura verbalized how her bilingualism became an asset for her calculations of mathematical concepts. Laura stated how she thought of basic arithmetic computations in Spanish while rationalizing more complex computation in English:

> If I am multiplying by 2, I usually break it down to an addition problem. For example, 16x2 would be 16+16 in my head, and I would count it as *seis mas seis* (six plus six), *uno mas uno* (one plus one), but the result would be thirty-two, not *treinta y dos* in my head.

Laura performs mental addition in Spanish; this extends to multiplication, which she interprets as a complex arithmetic skill, and breaks down into addition. However, she thinks of the result in English. For those participants whose mathematical education was entirely in Spanish, their bilingualism needed to be supplemented by the translation capabilities of the software as shown in AS1 (Figure 4.1) or through the use of online translators, AS2 (Figure 4.2).

The subjects in this online pre-calculus course utilized online translators when the software translator was not sufficient for understanding the explanations and instructions. The software's translations were in a Spanish dialect participants did not recognize or were written in an unfamiliar form. The unfamiliarity with the translations created a contradiction with their language. Alvaro reported: *"Como que el lenguaje estaba poquito diferente, y me confundía"* [It's like the translation language was a little different and it would confuse me]. Although the translations provided by ALEKS are academically accurate, the dialect used by the software designer was not culturally relevant for Alvaro, thus leading to his confusion.

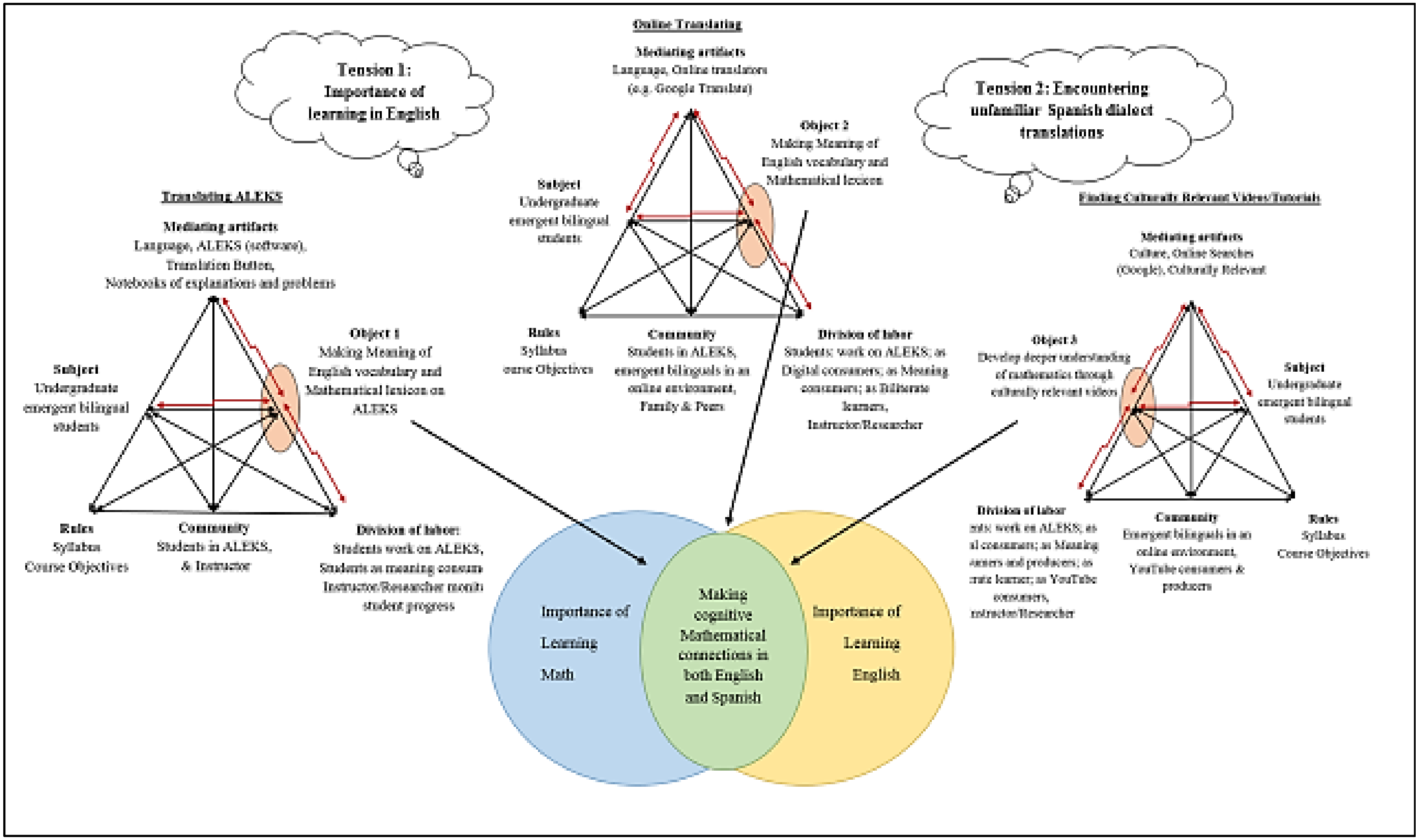
Participants initiated searching the internet for translations of English vocabulary or mathematical terms, utilizing online translators such as Google Translate, or Dictionary.com. As Rosario, a Digital informant from spring 2016 stated, "When I do not understand a math term I usually look it up on Google…" Their motivation for translating the explanations and/or key

terms was to make meaning of the terms. Meaning making was the object of the first two activity systems, object 1 in AS1 (Figure 4.1) and object 2 in AS2 (Figure 4.2).

Object and Outcome

In each activity diagram, AS1 (Figure 4.1), AS2 (Figure 4.2), and AS3 (Figure 4.3), the object or motive for the activity is depicted by an oval to indicate that the object-oriented actions are explicitly and/or implicitly characterized by ambiguity, interpretation, surprise, and change (Engeström, et al., 1999). For AS1 (Figure 4.1) and AS2 (Figure 4.2), the object that motivated the participants was to make meaning of English vocabulary and mathematical lexicon. Through an Activity Theory lens, participants' continual reflection of their activity prompted them to create two activity systems for meaning making. Object 3 in AS3 (Figure 4.3) was motivated by their desire to create a deeper understanding of mathematics through the mediation of culturally relevant videos. The combination or network of all three activity systems led to an overall outcome which was to make cognitive mathematical connections in both English and Spanish (Figure 4.4).

Figure 4.4. Network of all three activity systems showing tensions which influenced change in activity systems.



The object for both AS1 (Figure 4.1) and AS2 (Figure 4.2), translating ALEKS and utilizing online translators was to make meaning of English vocabulary and mathematical lexicon. Fernando stated: “I change it [ALEKS] when I don’t know the meaning of a word or concept because all my previous algebra and math knowledge is in Spanish.” Fernando, like many participants, translated one or two problems on ALEKS when he did not understand the mathematical vocabulary. He also translated to make a cognitive connection between the mathematics he learned in Spanish and those learned in this online pre-calculus course. Oscar continued with the idea that future mathematics will be learned in English: “I try to understand ALEKS in English because I will be using it in the future, so understanding it in Spanish it may make harder future topics.” The final outcome of making cognitive connections with the mathematics in both languages was an important motivator for these participants.

Participants translated the software when taking the midterm exam, usually for either just one or two problems or for the entire exam. In fact, a combined 40% of the Digital informants translated the software for these purposes. The high stakes aspect of an exam influenced their decision to change the exam. Keith stated he translated the entire midterm exam because he did not want to commit any errors on the problems by misunderstanding the instructions or terms. However, several participants only translated the program for one or two questions. As explained by Fernando: “I did changed the language setting to Spanish in two questions just to make sure I was understanding concepts correct.” Fernando underscored the importance for a cognitive understanding of the concepts while maintaining a sense of urgency in keeping most of the exam in English.

When participants encountered difficulties with the software translations, they utilized online translators. The rationale for searching the internet for meaning of English register and lexicon was similar for translating the software. The translations participants found in and outside of ALEKS to make meaning of mathematical syntax was ultimately the activity motivated by the final outcome to understand the mathematical terms in both languages. When the translations were not sufficient for understanding the mathematics, participants searched the internet for tutorial videos, as explained in AS3 (Figure 4.3).

Searching for videos that presented mathematical concepts not only in Spanish but in a dialect that the students were familiar with allowed participants to make cognitive connections between topics they were studying in ALEKS and what they had learned in their native language. Searching for online math tutorials was reported by most participants. Susi reported that she searched Khan Academy (a series of free, online, student-oriented tutorials on a variety of academic subjects) for math videos in her native language when the online translations of terms were not in a mathematical context. Ray stated: "When I do not understand a math term problem, I look for aid in YouTube videos." In order to achieve the final outcome of making cognitive connections with the mathematics in English and Spanish, participants focused their searches on culturally relevant videos.

When participants viewed a tutorial video in Spanish, they first verified if it was in a Spanish dialect with which they were familiar. Gracia noted that she could tell if the tutor on the video was a native speaker: *"Pos es, es como lo hablan… Porque muchas veces pueden hablar, pueden no saber español pero pueden."* [Well, it's how they speak it… Because many times they can speak it, they may not know Spanish [well], but they

can speak it]. It was Gracia's opinion, which was shared by other participants such as Susi, that the tutors on Khan Academy were not native Spanish speakers. Hence participants continued to search the internet until they found culturally relevant videos.

Culturally relevant videos were videos that presented mathematical topics in a Spanish dialect that emergent bilinguals understood as well as videos that presented the mathematical topic utilizing a method with which they were familiar. For example, as displayed in Figure 4.5, the video entitled "Trigonometría Básica Parte 1" was a Spanish-language Khan Academy tutorial on basic right triangle trigonometry.

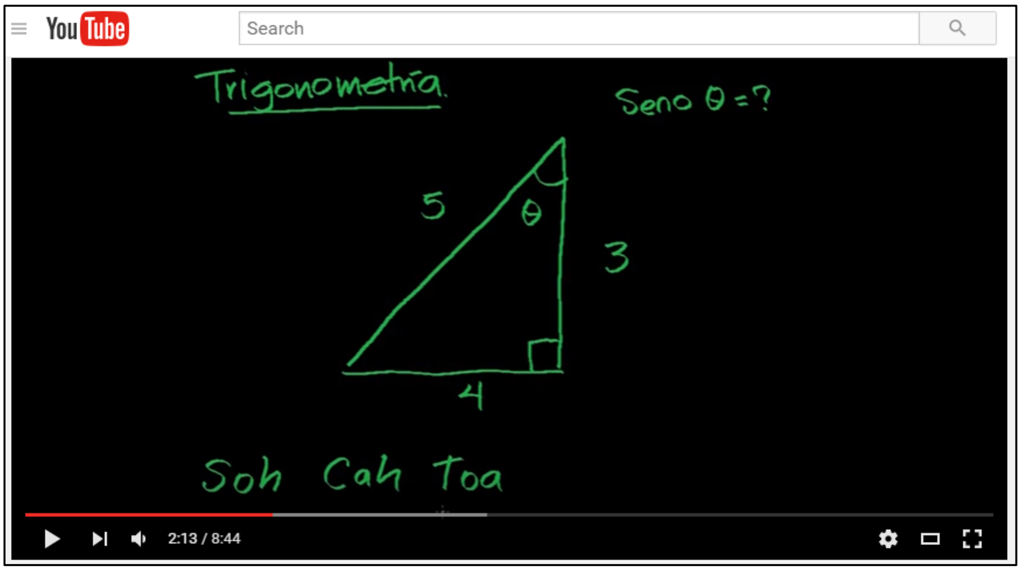


Figure 4.5. Khan Academy video, "TRIGONOMETRÍA BÁSICA PARTE 1" on basic right triangle trigonometry using the American mnemonic SOH-CAH-TOA: As of April 23, 2017, the full video from which this image was taken is available at https://www.youtube.com/watch?v=wA13cK9x8wI

The tutor in this video is explaining the ratios, or fractions, for the trigonometric functions sine, cosine, and tangent associated with the angle between the sides of length 5 and 3, labeled with the Greek letter *theta*. These ratios are defined as follows:

$$\mathbf{S}\text{in}(\theta) = \boldsymbol{O}pposite\ side\ \div \boldsymbol{H}ypotenuse = \frac{Opp}{Hyp}$$

$$\mathbf{C}\text{os}(\theta) = \boldsymbol{A}djacent\ side \div \boldsymbol{H}ypotenuse = \frac{Adj}{Hyp}$$

$$\mathbf{T}\text{an}(\theta) = \boldsymbol{O}pposite\ side \div \boldsymbol{A}djacent\ side = \frac{Opp}{Adj}$$

The ratio for the sine of the angle *theta* is equal to the side opposite the angle divided by the hypotenuse of the triangle. In this example, this ratio for the sine function is given by the fraction $\sin(\theta) = \frac{4}{5}$. In the United States students, are taught to remember these ratios using the mnemonic, SOH-CAH-TOA, where SOH represents $\mathbf{S}\text{in}(\theta) = \boldsymbol{O}pposite\ side\ \div \boldsymbol{H}ypotenuse$, CAH signifies $\mathbf{C}\text{os}(\theta) = \boldsymbol{A}djacent\ side \div \boldsymbol{H}ypotenuse$, and TOA represents $\mathbf{T}\text{an}(\theta) = \boldsymbol{O}pposite\ side \div \boldsymbol{A}djacent\ side$. Like many mnemonics, this one is utilized by educators to help students remember the ratios of the basic trigonometric functions.

Participants who learned trigonometry in Mexico had not seen this mnemonic for the trigonometric functions. Marco provided the link to this video in an email correspondence as an example of a video that, although in Spanish, was not useful in helping him understand the trigonometric functions. He did not understand the mnemonic; therefore, he searched for other tutorial videos. During face-to-face interviews, this video was shown to another Digital informant, Gracia, and she concurred that she would not use this video as a tutorial and would continue her online search for videos that presented the material in a culturally relevant format. Finding culturally relevant videos along with the translation of key terms and vocabulary mediated participants' final outcome of learning mathematics in both English and Spanish.

Rules

The rules of an activity system are the informal and formal regulations that govern the subjects and community in the activity they are participating in (Blunden, 2010; Engeström, et al., 1999; Engeström, 2001; Kaptelinin & Nardi, 2012; Roth & Lee, 2007; Yamagata-Lynch, 2010). For this fully online pre-calculus course, a course syllabus was sent to students before the beginning of each semester (See Appendix E). The syllabus contained the course information, course procedures, as well as instructions on how to purchase and log into the course software, ALEKS.

Students were required to log into ALEKS a minimum of eight hours per week, where a week began at 12:01 AM Monday morning and ended at 11:59 PM Sunday night. Students who did not complete eight hours each week were in jeopardy of being dropped from the course. If a student failed to meet the required eight hours in one week, they were sent an email informing them to re-read the syllabus section on the 8-hour course policy. The 8-hours policy was stated on the syllabus as follows:

> Students must work on ALEKS a minimum of 8 hours per week. Failure to work on ALEKS 8 hours per week may result in you being dropped from the course. Students are recommended to complete a minimum of 25-30 topics per week in order to complete this course successfully.

On average, 20% of students in each semester were dropped from the course when they spent less than eight hours on ALEKS during each of three consecutive weeks.

An initial assessment on ALEKS, called a knowledge check, was completed by each student at the beginning of the semester. Once students completed the initial knowledge check, they were required to complete the topics assigned to each of three intermediate objectives (Figure 4.6). A topic is completed when three consecutive practice problems are correctly

answered on ALEKS. The practice problems are found by clicking on the phrase "CONTINUE MY PATH" found on a student's home page in ALEKS. After completing 20-25 practice problems, students are automatically given a formative assessment, another knowledge check, to complete. These knowledge checks automatically appear and are provided by ALEKS to

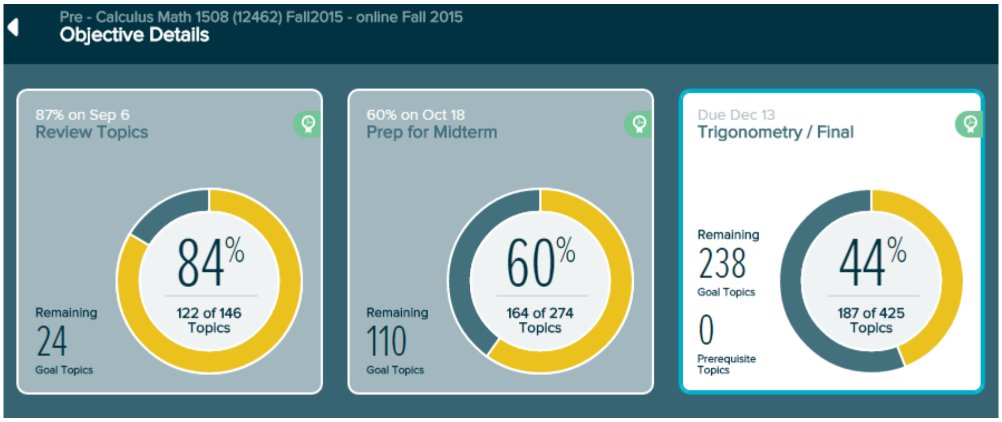


Figure 4.6. View of Objectives in ALEKS.

determine mastery of the topics practiced. There were also two exams given in each semester, a midterm exam and a comprehensive final exam. The grade calculation for this class was as follows.

Review Topics	5%
Forum questions	5%
Prep for Midterm	10%
Midterm Exam	30%
Trigonometry	15%
Final Exam	35%

There were no regulations restricting students from utilizing the internet or online tutors for assistance in this class. Students were encouraged to create a digital community, through the course forum, to assist their learning of the topics for this course.

Community

The community in an activity system is one of the socio-historical components in mediated action (Blunden, 2010; Engeström, et al., 1999; Engeström, 2001; Kaptelinin & Nardi, 2012; Roth & Lee, 2007; Yamagata-Lynch, 2010). The community consists of the social group the subject belongs to while participating in an activity (Engeström, et al., 1999; Engeström, 2001; Yamagata-Lynch, 2010). The communities for all three activity systems were similar, though, each community expanded in response to the digital activity in which the participants were engaged.

The community in AS1 (Figure 4.1) consisted of the students enrolled in an online pre-calculus class that utilized the ALEKS software, along with the instructor/researcher. These students logged into ALEKS to work on the class required practice problems, knowledge checks, and exams. In general, participants felt that ALEKS mediated their learning of the pre-calculus topics in a positive way. Esmeralda's statement is representative of this general sentiment:

> Being the first time I'm using the ALEKS program, it really helps me to really understand the different topics to learn. In the Initial Knowledge check, I remembered how to work out most of the problems given, and the ones I had completely forgotten about, they were taught to me in an understanding way later on in the course.

Tensions within this community arose when the subjects encountered unfamiliar Spanish dialects or translations, creating an obstacle to their meaning making of the vocabulary and instructions on ALEKS. Gracia proclaimed: *"Por lo regular si no entiendo algo repaso el procedimiento muchas veces. Si ya de plano no entiendo busco en internet"* [Usually if I don't understand something I review the procedure many times. If I still don't understand I look for it

on the internet]. This tension led to the second activity system developed to explicate participants' use of online translators.

In AS2 (Figure 4.2), Online Translating, the community expanded from the students enrolled in the online pre-calculus class, ALEKS, and the instructor/researcher to include emergent bilinguals in an online environment, family, and peers. Once a learner logs onto the internet, an online community is created with fellow consumers and producers of online content. Thus, the community in AS2 (Figure 4.2) has grown to include family, peers, and producers of bilingual content as well as mathematical content.

The subjects in this community encountered a similar tension as with AS1 (Figure 4.1): an unfamiliar Spanish dialect or translation. When emergent bilinguals utilized an online translator, e.g. Google translate, they encountered definitions that were out of mathematical context or in a different dialect. Describing his response to this, Ray stated: "When I do not understand a math term/ problem, I look for aid in YouTube videos." In other words, to overcome these obstacles, emergent bilinguals in the community develop yet another digital practice: searching the internet for culturally relevant videos.

As depicted in AS3 (Figure 4.3), the subjects became a part of a culturally relevant online community. In seeking out assistance with mathematics assignments, they became online video consumers and producers and emergent bilinguals in an online environment. In this community, emergent bilinguals searched for videos that not only were in Spanish but were culturally relevant. Emergent bilinguals searched for videos in a Spanish dialect that they could understand or for videos utilizing methods they had learned in their monolingual Spanish math classes. These videos, in turn, allowed them to make cognitive connections between the lesson in

ALEKS and the language of instruction, which was the ultimate outcome for emergent bilinguals in this online pre-calculus course.

Division of Labor

The roles and tasks the community undertakes are defined as the division of labor in an activity system (Blunden, 2010; Engeström et al., 1999; Yamagata-Lynch, 2010). In AS1 (Figure 4.1), the undergraduate emergent bilingual students worked on ALEKS as defined in the course syllabus. They mediated the translation capabilities of ALEKS for meaning making of English vocabulary and mathematical lexicon, developing their role as meaning consumers. The instructor's role in AS1 (Figure 4.1) was to monitor students' progress in ALEKS.

The instructor utilized ALEKS-generated progress reports and time-on-topic reports to monitor students' progress with the program and maintain communication with students. If a student's progress digressed then an email was sent to the student to inform them of the problem and provide solutions, such as tutoring or additional time on ALEKS. As the researcher, the instructor posted course forum questions and collected data for analysis.

In the second activity system, AS2 (Figure 4.2), the emergent bilingual students' tasks were to continue working on ALEKS as well as expand their digital roles as biliterate learners. As they utilized online translators to make meaning of vocabulary and terms, emergent bilinguals' roles evolved into digital consumers and meaning consumers. The dialectical relationships between these new roles, the community, and the mediated artifact of online translators allowed emergent bilinguals to begin to transform their mathematical academic literacy, which is a key concept of third generation Activity Theory.

Creating mathematical academic literacy was further accomplished by the mediation of culturally relevant videos. In AS3 (Figure 4.3), the subjects continued to have the tasks of

working on ALEKS; however, their roles now included becoming digital consumers and biliterate learners. Their roles in this activity systems would continue to grow as meaning consumers and producers. Emergent bilinguals were not only consumers of meaning making translations, but they began producing meaning of mathematical terms by computing the answers to practice problems. They were online consumers of culturally relevant videos, which allowed them to produce meaning and understanding of the mathematical content they were learning. They were further producing cognitive mathematical connections in both English and Spanish through the mediated artifacts, ALEKS translations, online translators and culturally relevant videos.

Mediating Artifacts/Tools

Mediating artifacts are tools that act as resources for the subjects in an activity and can include physical objects, such as social others; books and computers; and non-physical objects, such as language and prior knowledge (Engeström, et al., 1999; Engeström, 2001; Kaptelinin & Nardi, 2012; Yamagata-Lynch, 2010). The interaction between the mediating artifacts and the subjects produces a cognitive tool for the mediated action within the activity (Yamagata-Lynch, 2010). These tools may change depending on the subject's object-oriented activity and the value of the tool for that activity (Yamagata-Lynch, 2010). Engeström (1999, 2001) developed an Activity Theory based on the tensions and systemic contradictions that are triggered by human activity (Engeström, et al., 1999; Engeström, 2001; Yamagata-Lynch, 2010). Emergent bilinguals in this study encountered two contradictions or tensions while engaged in this fully online mathematics course.

Emergent bilinguals mediated their utilization of ALEKS translations, online translators, and culturally relevant videos for the outcome of making cognitive mathematical connections in

both their native language and the language of instruction for an online pre-calculus course. The first tension was encountering an unfamiliar Spanish dialect or translation while engaged in activity systems AS1 (Figure 4.1) and AS2 (Figure 4.2). The second tension was the importance emergent bilinguals placed on learning English, consequently, learning mathematics in English. In order to make cognitive connections in both languages, emergent bilinguals searched for online video tutorials, AS3 (Figure 4.3), where they encountered unfamiliar Spanish dialect and translations again.

ALEKS translating capability. Figure 4.7, depicts a screen shot of an ALEKS practice problem that was translated into Spanish. Emergent bilinguals' academic literacy in mathematics presented two challenges for them. First, they were required to understand mathematical reasoning, thinking, and metacognition, as well as academic language proficiency.

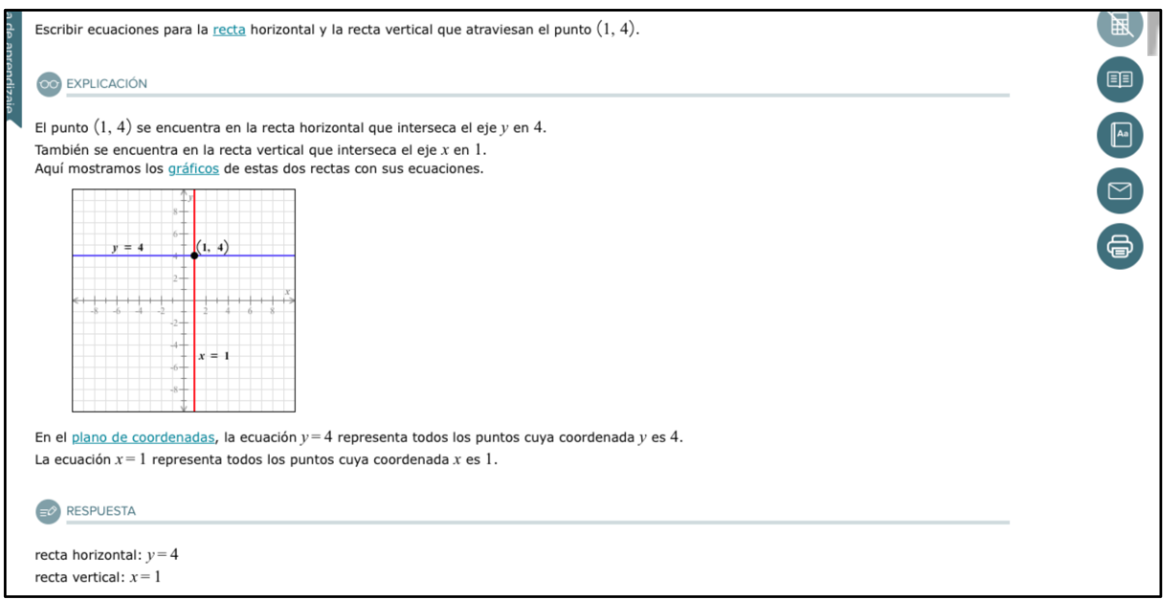


Figure 4.7. An example of an ALEKS practice problem translated into Spanish.

These challenges along with the importance they placed on learning English while taking a mathematics course developed into the tensions that transformed their activity and mediated artifacts.

Emergent bilinguals performed the action of clicking on the translation button on ALEKS to mediate their understanding of English vocabulary and/or mathematical terminology. When a participant did not understand a mathematical term, they translated the software. Rosa stated:

> I have switched it [ALEKS] to Spanish twice. Especially with the word problems, because there are still some sentence structures that get confusing like "3 times as much." I never know which is the bigger one the one on the left or the one on the right. So if I switch it to Spanish I can then sort of decode what it means.

Rosa, like her other emergent bilingual peers, attempted to make meaning of mathematical sentence structure in order to “decode” the meaning. Mediating the translation button on ALEKS allowed emergent bilinguals to acquire agency in their learning of the topics for this course.

For several participants, the translation capabilities of ALEKS were not ideal. Alvaro noted that the ALEKS translations seemed different for him; it confused him more than helped. The unfamiliar Spanish dialect or translation created a tension between the subject, the mediated artifact of translating ALEKS, and their role in the entirely ALEKS-based class. As described by Engeström et al. (1999) tensions which arise from human activity are the forbearers of change within the activity system or for the creation of a new system.

Online translators. Emergent bilinguals changed their activity when they encountered difficulties with the ALEKS translation. Anna proclaimed, “*Use herramientas como Google Translate o me referio a las explicaciones del tema para ver de lo que se trataban ciertos*

ejercicios" [I used tools such as google translate or I refer to the explanations of the topics to see what they are all about]. In this example, Anna was attempting to link the explanations of the topics with the mediated tool, Google Translate. She had translated ALEKS but was unable to understand the vocabulary; consequently, she turned to Google Translate for help.

At this point, Anna is creating a complex bilingual digital space where she has several browsing windows open, an online translator, ALEKS practice problems, and ALEKS translators. For Anna, comprehension of the English vocabulary or mathematical terminology was not deduced by translating the words alone. Hence she, like many of the emergent bilinguals who encountered this tension transformed her action by changing her activity to make cognitive connections between the mathematics and the English register.

Culturally relevant videos/tutorials. Tensions that arise from systemic contradictions can act as "an obstacle, making it difficult for the subject to attain the object, or by taking a role as an enabling influence for the subject to attain the object" (Yamagata-Lynch, 2010, p.2). Use of the ALEKS translator button and online translators was due to a lack of mathematical and English academic language proficiency. This obstacle created two activities that emergent bilinguals engaged. Anna realized that in order to fully understand the mathematical concepts, she required more than a simple translation of the vocabulary. She needed the mathematical concept to be presented in her native language. This realization influenced participants to search for online culturally relevant videos.

Emergent bilinguals mediated the use of culturally relevant tutorial videos to create a bilingual digital space for this online course. Their mediation of these videos also created new tasks and roles. The division of labor for emergent bilinguals in this course expanded to include digital consumers and YouTube consumers. Emergent bilinguals were not only meaning

consumers at this point; they were transforming themselves and their digital community to meaning consumers and producers.

As biliterate learners, emergent bilinguals were creating a digital space in which they acquired agency for their learning of the mathematics. They translated the online software to make meaning of vocabulary and terms to become meaning consumers. They altered their actions to expand their activity to include online translators outside of the software itself. The tensions were still present in both activity systems, thus influencing an evolution to a third action of searching for culturally relevant videos. Combining these three activity systems allowed emergent bilinguals to develop a bilingual digital learning environment through meaning consumption and production. They developed the ability to understand the mathematical lexicon and English vocabulary so as to comprehend the mathematical lessons in both English and Spanish. This bilingual comprehension was the final outcome of the network of activity systems.

Summary of Chapter 4

In this chapter, the complex learning environment of a fully online pre-calculus course was described through supporting qualitative results. There was a variety of interacting factors that influenced emergent bilinguals' mathematical academic literacy [object] and their creation of a bilingual digital learning environment [outcome] in which they could thrive. The course regulations [rules] as described in the syllabus did not restrict emergent bilinguals from searching for translations of English vocabulary and mathematical lexicon. Emergent bilinguals were also influenced by a fluctuating online environment [community] which began in an intelligent tutoring system and ebbed and flowed into a fully biliterate online environment. Their roles [division of labor] in each action they undertook to create meaning of vocabulary and terms

was mediated by the activity they were engaged in, and by the tools [mediating artifacts] they utilized to attain their object.

The two main tensions, (1) the importance of learning English and (2) encountering unfamiliar Spanish dialects or translations, influenced the development of each activity system, AS1 (Figure 4.1), AS2 (Figure 4.2), and AS3 (Figure 4.3). These tensions further influenced the creation of a network of activity systems to explicate how emergent bilinguals' final outcome became a reality. They were able to develop cognitive connections in mathematics in both English and Spanish. Further analysis of the data will be presented in Chapter 5, where it will focus on funneled informants Marco, Gracia, Rosario, Ray, Keith, and Susi. Chapter 5 will also include quantitative analysis presented through descriptive analysis and diagrams. Chapter 6 will present the limitations, implications, and conclusions for this study.

Chapter 5

Findings

Overview

The goal of an embedded-exploratory design is to collect and analyze both qualitative and quantitative data in parallel. Activity Theory supports a systematic approach to enhance understanding of student activities and interactions that are situated in a complex real-world environment (Engeström et al., 1999; Yamagata-Lynch, 2010). Utilizing an Activity Theory methodology allowed me to extract the essence of emergent bilinguals' digital practices while engaged in a fully online mathematics course. Graphical models of participants' activity systems allowed the researcher to organize complex data from a real world setting of a college course and the virtual world of an online mathematics course into a reliable interpretation. The dialectical contradictions and tensions that arose in emergent bilinguals' activity systems were between the mediated artifacts and objects. These contradictions enabled participants to create mathematical knowledge utilizing both Spanish and English.

In this embedded-exploratory design, findings emerged from the analysis of qualitative data that was additionally supported by findings from quantitative data (Creswell & Clark, 2007). The embedded-exploratory methodology utilized in this study provided access to the lived experiences and digital practices of emergent bilinguals participating in a fully online pre-calculus course over four semesters. This study endeavored to develop a deeper understanding of emergent bilinguals meaning making digital practices in an online pre-calculus course.

This study fills the research lacunae on emergent bilinguals' engagement in online courses, digital practices in an online mathematics course, and digital literacies in online mathematics courses. This research also enhances the literature on emergent bilinguals'

mathematical and technology self-efficacy in an online mathematics course. While studies on attitudes, *translanguaging*, and effective intervention strategies for increasing emergent bilinguals' mathematical comprehension or placement in mathematics courses are readily available, there are few if any studies that examine emergent bilinguals' digital practices for meaning making in online mathematics courses. The analysis of emergent bilinguals' activity systems, which consisted of, utilizing online translators, translating the course software, and searching for online culturally relevant tutorial videos, allowed for the discovery of emergent bilinguals' online perspectives and digital practices.

Purpose of this Study

Studies on the benefits of adopting online mathematical software to support diverse languages and cultures have been conducted by several researchers (Casas, Goodman, & Pelaez, 2012; Griffiths, Heppell, Millwood, & Mladenova, 1994). In these studies, student's motivation to work on mathematics increased as did their desire to use a cognitive tutor with translation capabilities for future math and science classes (Casas, et al., 2012). The lacuna in the emergent bilingual literature on how these students participate in hegemonic monolingual online math courses is where this study will be situated. My role as a researcher was to reveal the complex digital practices of emergent bilingual students in meaning making strategies for an online pre-calculus course and how their self-efficacy was affected by their evolving digital practices.

Through the extensive literature review, a set of tools was identified and utilized in both English and Spanish: demographic surveys, a math self-efficacy survey, a math and technology survey, course forum posts, daily logs, screenshots, and email-interviews (see Appendices F, G, H, J, K, M, and N for descriptions of each instrument). Data was collected in four stages from a pre-calculus class offered for each of four semesters. The final Funneled informants were

identified through a sequential mixed methods sampling technique adapted from Teddlie and Tashakkori (2012). See Chapter 3 for a detailed description of this funneling process.

Preview of Findings

Through a cross tabulation and content analysis of the demographic survey with the course forum posts, 35 Spanish-dominant emergent bilinguals were identified for in-depth email interviews. Of these 35 participants, 15 Digital informants provided in-depth information about their digital practices. Data from course forum posts revealed that Digital informants translated the software for meaning making of mathematical syntax and English vocabulary. They reported that they translated the software for the midterm exam to understand the instructions fully. They also translated the midterm exam to connect the midterm problems to prerequisite topics they had learned in Spanish.

Results from email-interviews revealed that Digital informants utilized online translators when the translations provided from ALEKS were confusing or in a Spanish dialect with which they were unfamiliar. They also reported that they searched the internet for culturally relevant videos to connect their meaning making digital practices with the topics in ALEKS. Four key themes were identified that provided a foundation for the development of emergent bilinguals' activity systems in an online pre-calculus class: (1) the importance of learning English; (2) translating software to Spanish and using online translators; (3) meaning making; and (4) students creating a bilingual digital learning environment.

The findings in this study revealed how a network of activity systems supported emergent bilinguals' meaning making of mathematical content. In this research study, I will discuss how emergent bilinguals' contradictions and tensions, encountered for meaning making, were a catalyst for creating mathematical cognitive connections in English and Spanish. It is imperative

that the voices and digital practices of emergent bilinguals in online mathematics courses are brought to light. All names used in the following descriptions are pseudonyms.

Digital Informants

In each semester, participants in this study were grouped into focus groups as determined by the cross-tabulation feature on Qualtrics as well as by participants' responses to the course forum posts. Each semester, email interview questions were sent to the Spanish-dominant focus group to elaborate on their course forum posts (see Appendix N for a full list of email questions written in Spanish and English). Of the 35 Spanish-dominant emergent bilinguals in the focus groups, 15 responded to these emails, allowing for further correspondence and trust to occur between the researcher and participant. These 15 Digital informants were Marco, Anna, Angelica, and Oscar from the fall 2014 pilot study; Laura, Esmeralda, and Leonel from fall 2015; Gracia, Fernando, Jaime, and Rosario from spring 2016; and Alvaro, Susi, Keith, and Ray from the 2016 fall semester.

Table 5.1 displays the two focus groups discuss in this section and the semesters during which they were recruited. Table 5.1 also shows that only two Funneled informants completed both MTAS and MSES pre- and post-surveys. Self-efficacy surveys were not collected during the fall 2014 and fall 2105 semesters; therefore an 'X' in the survey columns on the right of

Table 5.1.

Table of participants by the information they provided.

	Digital informants - number of participants who provided email responses	Funneled informants - number of participants who provided meaningful data	completed MTAS survey	completed MSES survey	completed both surveys
Fall 2014	Marco (14)	Marco (14)	X	X	X
	Anna (14)		X	X	X
	Angelica(14)		X	X	X
	Oscar (14)		X	X	X
Fall 2015	Laura (15)		X	X	X
	Esmeralda(15)		X	X	X
	Leonel(15)		X	X	X

Spring 2016	Gracia (16)	Gracia (16)	Gracia (16)		Gracia (16)
	Fernando (16)				
	Jaime (16)			Jaime (16)	
	Rosario (16)	Rosario (16)	Rosario (16)	Rosario (16)	Rosario (16)
Fall 2016	Alvaro(F16)				
	Susi (F16)	Susi (F16)	Susi (F16)	Susi (F16)	Susi (F16)
	Keith(F16)	Keith(F16)			
	Ray(F16)	Ray(F16)			

Table 5.1 depicts this fact. These email interviews and constant comparisons between the forum posts and participants' email responses produced, copious, in-depth information about their lived digital experiences that was used to narrow the axial coding. This coding revealed greater insights in participants' activity systems for meaning making, translating the software, and using online translators. The data also supported the tension participants felt about the importance of learning English in a mathematics course.

Funneled Informants

In this section, I will discuss the respective analysis of data collected from each Funneled informant. Through a sequential mixed methods sampling (Teddlie & Tashakkori 2012), participants were funneled into focus groups of decreasing size. The first focus group was the Digital informants consisting of 15 participants (see Table 5.1). These were participants who provided in-depth information on course forum posts. Funneled informants were 6 participants selected from the Digital informant for face-to-face interviews. As there were 6 total funneled participants, there are 6 subsections to follow.

Marco. Marco was a soft-spoken participant, recruited from the fall 2014 semester, who self-identified as a Hispanic/Latino. Marco was born and attended school in Juarez, Mexico until he attained his diploma from *preparatoria* (high school) and enrolled at the University of Texas at El Paso, where he registered for this online pre-calculus course. Throughout his education in Mexico, Marco's mathematics classes were taught entirely in Spanish, so he mentally processed mathematical concepts in his native language. In his words: "My native language is Spanish, so

[it] is easier to me thinking in Spanish than English." Marco was the only Funneled informant to respond to most digital inquiries in English, in his face-to-face interview, Marco expressed that he felt strongly about speaking and writing in English. This foreshadowed the tensions that arose from the importance of learning English while taking a mathematics course and other findings in this study.

Marco found that making meaning of a single mathematical term using his paperback dictionary, *Larousse Gran Diccionario: English Spanish*, was not enough to fully comprehend the explanation of the topics presented by ALEKS. He stated: "Sometimes I see in the topic and I don't understand what I need to do. So, when I changed to Spanish I can understand all the instructions [explanations], and I start to work." Marco's misunderstanding of the Spanish dialect or translation prevented him from meaning making by searching for the definition of one or two words in his pocket dictionary. Marco transformed this activity into translating the software to Spanish in order to make meaning of explanations or instructions. Marco translated the software into Spanish at the beginning of the semester. However, he decided to change ALEKS into English after the midterm in order to learn the topics in English reaffirming his attitude towards the importance of learning English.

Marco's learning trajectory (Figure 5.1) is presented as a graphical representation of his formative assessments and topics practiced as compiled from ALEKS. Marco's trajectory did not decline after the Midterm; in fact, a significant increase in the percentage of the number of topics completed can be observed in his learning trajectory starting right before the midterm exam. The first striped bar in Figure 5.1 represents the percentage of the total number of topics (93) mastered on his initial knowledge check in his initial assessment. Each subsequent striped bar represents the percent of topics mastered with each completed knowledge check. The solid bars

in Figure 5.1 signify the percentage of the number of practice problems completed between knowledge checks, or the topics that Marco practiced and completed.

Marco's learning trajectory while keeping the software in Spanish shows that he constructed a concrete mathematical foundation by utilizing the translation capabilities of the software. Marco, who translated the software into Spanish almost the entire semester, spent over two hundred hours on ALEKS and successfully completed the course with an A. Gracia, another Funneled informant, translated the ALEKS software for the entire semester; however, her digital lived experiences differed from Marco's.

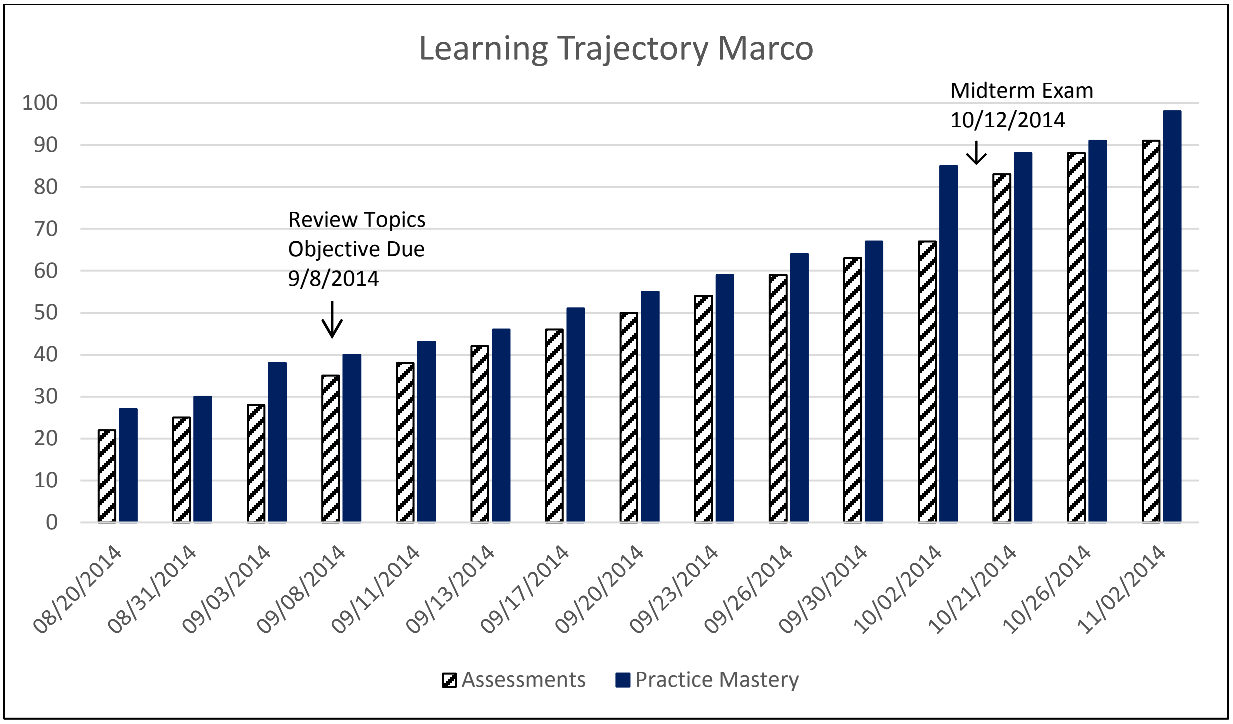


Figure 5.1. Learning trajectory for Marco showing the percentage of the number of topics mastered on his assessments (striped bars) and the percentage of the number of topics completed after each assessment (solid bars).

Gracia. Gracia was born in the United Stated but was educated in Mexico for most of her *primaria* (elementary school), *secundaria* (middle school), and *preparatoria* (high school). She identified herself as a Hispanic/Latina. Gracia's family moved to the United States so that she could attend high school in New Mexico, with the intention of providing her with greater educational, economic, and socioeconomic opportunities, as well as an opportunity to learn English. She attended high school for one and a half years in New Mexico before returning to Mexico; yet she felt that she learned very little English during her time in the U.S. After completing her high school requirements upon her return to Mexico, Gracia was offered a scholarship to attend the Universidad Autónoma de Ciudad Juarez, (UACJ). Before enrolling at the university, she was offered a job in El Paso, Texas, that offered her the opportunity to live and study in the United States. She decided that it would be in her best interest to take a year off from college to attain in-state residency, which would allow her to apply for financial aid and attend the local stateside university.

Up to the point of taking the pre-calculus course at the heart of this study, Gracia's course load at the university consisted entirely of English for Speakers of Other Languages (ESOL) courses. In the spring 2016 semester, she enrolled in this online pre-calculus course. It was not Gracia's intention to enroll in a monolingual mathematics course; however, there were no ESOL math courses offered, and she was advised to take this online course. After completing the initial assessment, Gracia attempted the ALEKS practice problems in English:

> *Haga de cuenta de que, al mero principio que puso ALEKS intente contestar unas cosas en inglés, entonces, me, me…o sea no le entendía mucho y eran de usar Google Translate o usaba un diccionario para ver verdad. Pero pos también hay veces que, que perdía tiempo en a ser eso. Entonces decía*

> *no pues mejor lo pongo en español, porque voy estar batallando mucho en estar, pos si en estar traduciendo y todo. Y si pos, por eso fue el motivo que lo cambie mejor a español. Y ya, así me, me aquede.* [Take into account that at the beginning of ALEKS, I attempted to answer a few things in English, then, I, I mean, I didn't understand much, and I used Google Translate or a dictionary to understand, right. But there were times that I lost too much time doing that. Then I decided it would be better if I put it in Spanish because I'll be struggling very much if I have to, well yes, if I have to be translating everything. So that was the main reason that I changed it to Spanish. And that's how I left it.]

She continued to work on the ALEKS software in Spanish for the duration of the semester. Nonetheless, Gracia's work schedule and misunderstanding of the syllabus caused her to fall behind in the completion of practice problems, and she performed poorly on her exams.

The ALEKS initial assessment Gracia completed (the striped bar dated "1/25/2016" in Figure 5.2) placed her in a knowledge state consisting of 23%, or 100 of the total number topics required for this pre-calculus course. Figure 5.2 illustrates that Gracia increased the number of topics practiced (solid bar) after each assessment. The dates on the horizontal axis shown in Figure 5.2 indicate that she was taking fewer assessments than Marco and they were Login Time Assessments, which indicated that two to three weeks were passing between logins onto ALEKS.

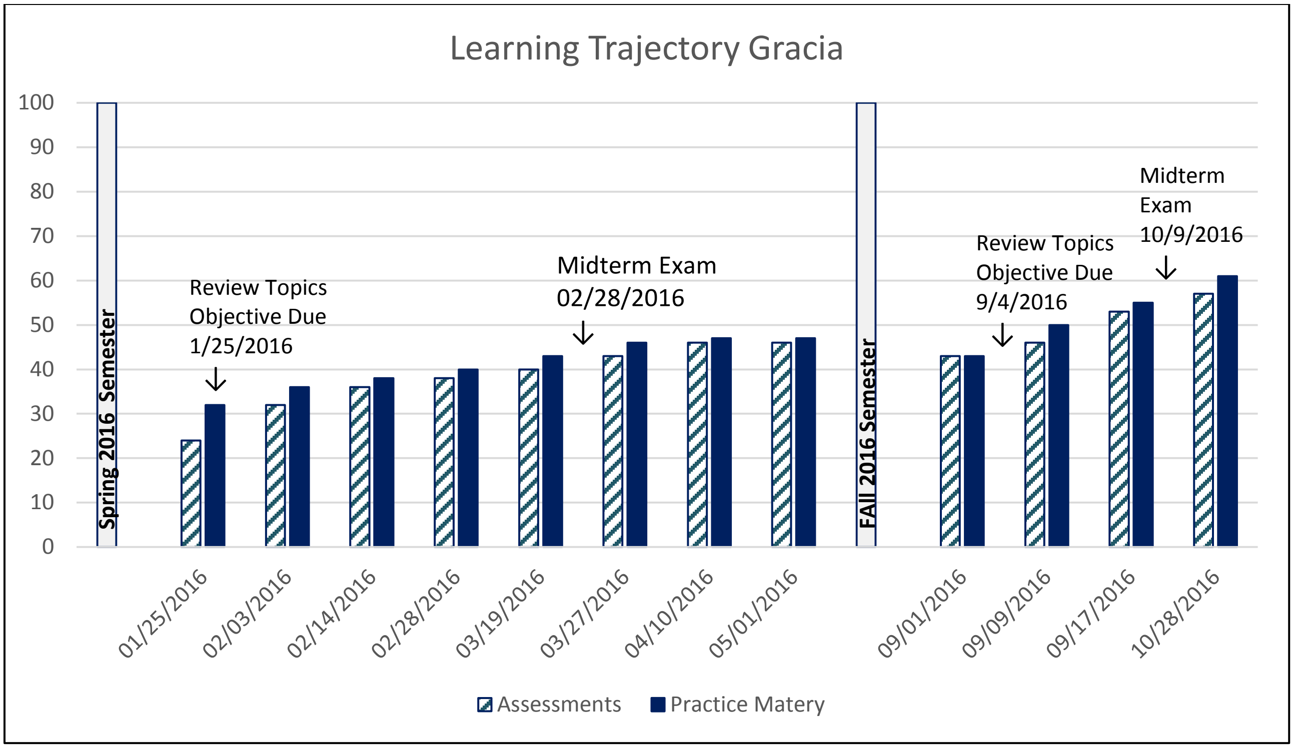


Figure 5.2. Learning trajectory for Gracia showing the percentage of the number of topics mastered on her assessments (striped bars) and the percentage of the number of topics completed after each assessment (solid bars).

Gracia did not successfully complete this online pre-calculus course in the spring 2016 semester. During her face-to-face interview, Gracia indicated that she worked in Mexico and had to commute most days from the university in the United States to her work in Juarez, Mexico. Gracia's meaning making digital practices, translating ALEKS and using Google translator, required more time than she was able to commit to the software in order to complete the course successfully. Hence, Gracia registered for the same online course in the 2016 fall semester.

Gracia, like many students and emergent bilinguals who enroll in a fully online mathematics course, reported that she enrolled for the flexibility an online class presumably

provides. Through the lens of Activity Theory, Gracia's online community expanded to include the locations where she logged in, her country of residence, her home, computer labs and/or locations with free Wi-Fi. Her role as an online student also included her role as a transfronterizo and salary earner. Transfronterizos are border-crossing students who participate in daily linguistic and cultural contact between two nations (de la Piedra, & Araujo, 2012; Relaño Pastor, 2007). These added roles and pressures determined how she engaged in this fully online mathematics course. These added obstacles and tensions were not the focus of this study; however, research on tensions involving emergent bilinguals as transfronterizos can build from the finding in this study.

There are two noticeable trends (see Figure 5.2) in Gracia's learning trajectory. One was that Gracia began the fall semester a few percentage points from where she left off in the spring semester. Gracia's final assessment in the spring semester was 46%, 197 topics mastered, and her initial assessment for the fall semester was 43% (179 topics mastered), a difference of 18 topics. Second, Figure 5.2 shows that Gracia's learning trajectory had a greater percent increase between each assessment in the fall semester. Gracia was able to mediate her digital practices in the fall semester to attain a grade of C and pass this online course.

When Gracia encountered unfamiliar Spanish dialects or translations on ALEKS or with Google Translate, she transformed her activities to searching online for Spanish language mathematical videos. She stated that she searched for video in which the tutors not only spoke Spanish but were native speakers:

> *Pos es es como lo hablan. Porque muchas veces pueden hablar, pueden no saber español pero pueden, o sea se les entienden la palabra…si le entiendes poquito pero hay otros que de plano pos no.* [Well, it is how they

speak it. Because many times they can speak [Spanish], they may not know Spanish, but you can understand their words…you can understand them a little, but there are others who you just can't.]

Gracia wanted to ensure that she not only understood the language in the videos but that she would be able to connect the lessons on the videos to the topics she was studying in ALEKS. Gracia utilized her digital practices of translating the ALEKS software and searching for online Spanish language math tutorials to create a bilingual digital learning environment.

> *Entonces, ya en mi próximo semestre si van a ser clases más difíciles porque por ejemplo tengo Criminología, y luego tengo, voy a tener biología, y esas clases ya, ya me, la 'advisor' me dijo, dijo ya para estas clases ya dijo ya nada va a ser fácil. Dijo porque ya son todas en inglés.* [Then, in my next semester, my classes will be more difficult because I have for example Criminology, and then I have, I have biology, and those classes are already, the advisor told me are already, my advisor said nothing will be easy. He said because they are all in English.]

Gracia was concerned that her subsequent classes would be of greater difficulty "*ya son todas en inglés* [they are all in English now]," because Gracia and her university advisor were both of the opinion that this monolingual online pre-calculus course was the same or similar to her other ESOL courses. The ability to translate the software and find culturally relevant videos offered Gracia the opportunity to transform this course into a bilingual digital learning environment. These experiences were common among the Funneled informants. Next, Rosario's story is outlined.

Rosario. Rosario was born and attended school in Juarez, Mexico until the sixth grade and identified herself as a Hispanic/Latina. Rosario was a participant in the spring 2016 semester. Rosario's basic arithmetic skills were learned in monolingual Spanish classes, and it was only when her family moved to the United States and she started middle school that she first enrolled in bilingual mathematics classes. Her high school mathematics classes, which began with Algebra, the first conceptually dominant math course, were taught in English.

Rosario learned numerical addition and subtraction as well as numerical multiplication and division in elementary school in Juarez, Mexico. The language of instruction for these arithmetic courses was Spanish; as a result, she performs these mental computations in the language of instruction, Spanish. Rosario's language of instruction for algebra, geometry, and trigonometry was English, at an American high school. Thus, Rosario thought of conceptual mathematical concepts such as a variable and the concept of slope in English. Consequently, she did not think translating the software into Spanish was necessary as a meaning making strategy.

Rosario's strategies for meaning making of mathematical terminology were to click on the explanation button on ALEKS or to find YouTube videos with examples of the topic she was working on, but not to use the translation capabilities on ALEKS unless it was absolutely necessary. Rosario's resistance to translating the software was connected to her transition from Spanish language math classes in Mexico to the English only math classes in high school. Her language of instruction dictated her thought process; Spanish for basic arithmetic and English for conceptual topics. This was mirrored by other funneled informants.

Rosario also felt that English was a dominant global language that would affect her future career choice thus making learning English very important for her. She wanted to ensure that she

learned mathematics in English and that she improved her English skills while taking this mathematics course. She stated:

> *Si es muy importante aprender las matemáticas en inglés, por la razón de que estamos en un país donde el inglés es muy común y muy dominante en la mayoría de los países del mundo* [Yes, it is very important to learn math in English, for the reason that we are in a country where English is very common and very dominant in most of the countries of the world.]

Her ideological attitude that English is the dominant language in the United States was similar to Marco's and other's attitudes about language. They felt that learning English leads to more economic and social opportunities in a society that privileges English (Achugar, 2008).

Rosario's prior knowledge of mathematics and conceptual terminology in English allowed her to have an initial knowledge state of 38% (163 of the total number of pre-calculus topics), as shown in Figure 5.3. Rosario had seven knowledge checks after the initial assessment before reaching 60% mastery, or 260 topics mastered. Figure 5.3 indicates that Rosario made a significant increase in the topics practiced the week before the midterm exam. This increase was a result of more time spent preparing for the midterm and the fact that all assessments, knowledge checks, were suspended one week prior to the midterm exam. Rosario completed 70% of the 307 topics for this course by the end of the semester, to earn a grade of C.

Rosario was a Spanish-dominant emergent bilingual whose language of instruction coincided with her transition to conceptual mathematics courses:

> If I change the program to Spanish, I would be able to understand because I know the language, but some mathematical terms [slope or intercept]

would be difficult for me to understand because I have never seen them before [in Spanish].

Although she thought in both Spanish and English to perform mathematical computations mentally, there were certain conceptual terms she only knew in English. Therefore she did not find it necessary to translate the ALEKS program as a meaning making strategy. Another Funneled informant with a similar educational history and transition of the language of instruction was Ray.

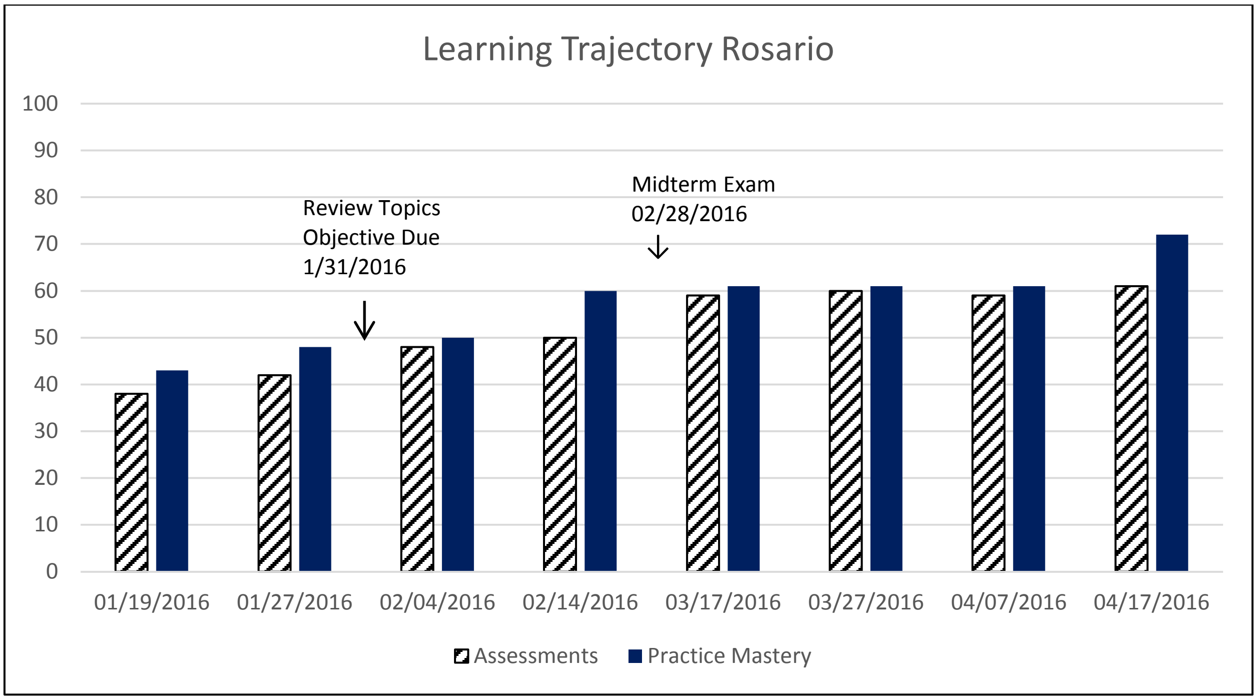


Figure 5.3. Learning trajectory for Rosario showing the percentage of the number of topics mastered on his assessments (striped bars) and the percentage of the number of topics completed after each assessment (solid bars).

Ray. Ray, a fall 2016 Funneled informant, identified himself as Hispanic/Latino and Spanish-dominant emergent bilingual who graduated from *primaria* (Elementary School) in Juarez, Mexico. During the time Ray was in elementary school, Juarez, Mexico was immersed in

a drug cartel war, where private citizens were targets for extortion and placed in harm's way through random violence. His family decided to move to the United States for the safety of the family and to provide a better education for Ray and his siblings.

Ray stated that he learned English in elementary school, but improved his English literacy at the high school he attended in the Unites States. The basic arithmetic mathematics classes he took while in elementary school were entirely monolingual Spanish classes. Ray stated that he thought in both languages, Spanish and English while performing mathematical calculations. When he initially opened or clicked on a new practice problem on ALEKS, he would scan the problem. While looking at the numbers, he thought of the arithmetic that might be necessary to solve this problem in Spanish, his language of instruction for basic arithmetic. When he read the problem, he found that while some vocabulary was easily interpreted and understood, the context of other vocabulary or mathematical terminology, which he had learned in a conceptual math course such as Algebra, caused him to change from Spanish to English in his mind:

> *Simplemente hay ideas o palabras que me hacen más fácil, o tengo, por ejemplo, una palabra de contexto que la tengo en ingles pero la estaba pensando in español, pues hago el cambio en la mente allí o pienso allí en español o Inglés.* [Simply put, there are ideas or words that I find easier, or I have, for example, a context word that is in English but I was thinking of it [arithmetic] in Spanish, then that's where I change it in my mind or I think in either English or Spanish.]

Ray had taken math courses with a greater degree of conceptual curricula, such as Algebra, Geometry, and Pre-calculus in monolingual English classes in the United States. This gave rise

to Ray's thinking in both languages while performing mathematics and was also why he felt it was not necessary to translate ALEKS into Spanish.

Ray stated, *"Y por lo menos no sentí la necesidad, ni si quiera el gusto de querer cámbialo a español"* [I did not feel the necessity in any least, not even for the pleasure of changing it [ALEKS] to Spanish]. Although Ray mentally thinks of mathematics in Spanish, he did not translate the software, in fact, his statement has a sense of defiance, *"ni si quiera el gusto…,"* [not even for the pleasure…]. He felt it was inappropriate for professionals to speak both languages simultaneously, translanguaging, but did think it was an asset to think in both languages for mathematics. His cultural experiences through relationships with family, peers, and teachers in Mexico was that it was not acceptable to mix both languages while speaking. He did comment on how translanguaging was common on the U.S.-Mexico border and that he was accustomed to speaking in both languages when engaged in a social conversation.

Ray was a finance major with a minor in computer science who had taken several online courses prior to the pre-calculus class, including, British Literature, History, and Government. This online pre-calculus course was his first online mathematics course and his first experience with the ALEKS software. Figure 5.4 depicts Ray's learning trajectory on ALEKS, with an initial assessment at 50% (211 of the total number of topics mastered). Just before the midterm exam, Ray reached 78% mastery of the total topics in this pre-calculus course; this was 418 topics. Figure 5.4 further shows how Ray began the semester with a high level of prior knowledge of the topics and then leveled off near 80% percent.

Ray stated that mathematics was a language in its own rights: "math is another language to which I am better accustomed to English terms." He was more comfortable with conceptual mathematical lexicon in English yet he still found it necessary to translate ALEKS "once or

twice." Ray's language of instruction transitioned from Spanish to English at the same time that his mathematical courses transitioned from fundamental arithmetic to conceptual mathematical content. This allowed him to understand the mathematical syntax in English. He translated the software only to understand certain mathematical vocabulary or when he encountered English syntax he did not understand. Ray's prior knowledge and 124 hours spent on ALEKS allowed him to attain an A for this course.

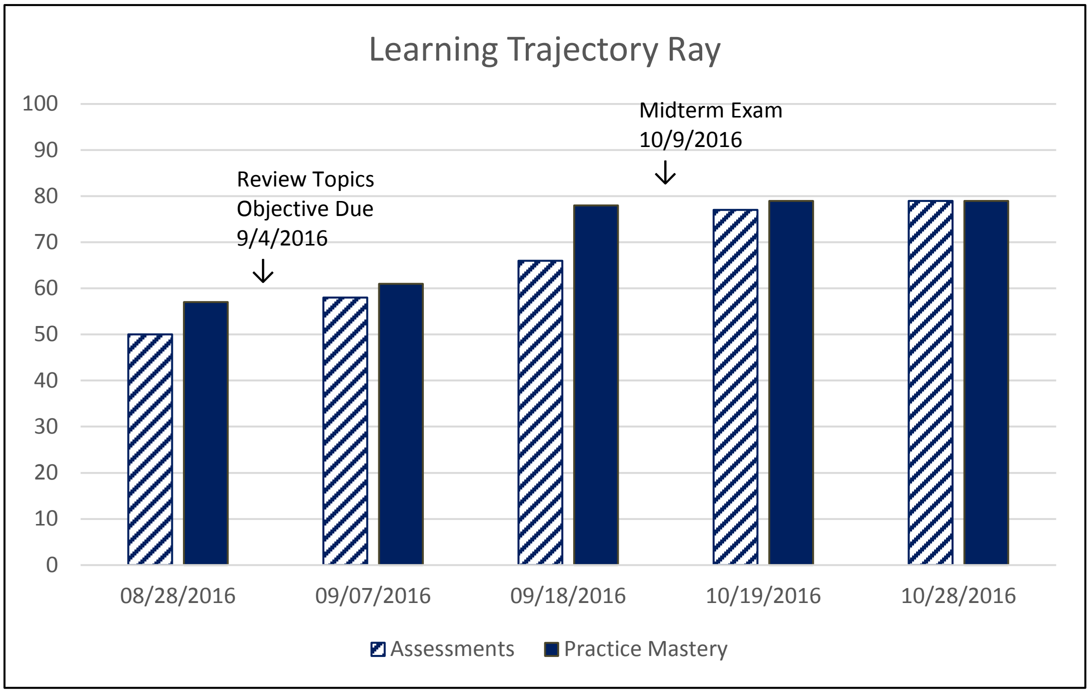


Figure 5.4. Learning trajectory for Ray showing the percentage of the number of topics mastered on his assessments (striped bars) and the percentage of the number of topics completed after each assessment (solid bars).

Keith. Keith was a Funneled informant from the fall 2016 semester, who completed his *primaria* (elementary school), *secundaria* (middle school) and *preparatoria (high school)* education in his hometown of Delicias, Mexico. He self-identified as a Hispanic/Latino and Spanish-dominant emergent bilingual. As an American citizen, Keith was of the opinion that he

would attain his college education from a university in the United States with one goal in mind, to learn English. He was in his first semester as a mechanical engineering major taking History and an ESOL class. He felt very comfortable in this online pre-calculus class due to the fact that he could change the language into Spanish for help with his comprehension of the topics: "*Y me siento más a gusto porque tengo ayuda en español* [I do feel very comfortable because I have help in Spanish]."

Keith stated that he did not translate ALEKS completely or throughout the semester; rather, he simply utilized the translation capabilities for certain mathematical terms.

> *Trato de…, bueno lo tengo en inglés, y trato de cambiar lo no más cuando no entiendo algunas traducciones. Por ejemplo algunas palabras que conozco en español que no las conozco en inglés como, como por ejemplo, una traducción e trigonometría.* [I try to..., well I have it in English right now, and I try to change it only when I do not understand some translations. For example, some words I know in Spanish but I do not know them in English like, like for example, a trigonometry translation.]

This illustrated how emergent bilinguals, such as Keith, utilized ALEKS for meaning making of mathematical terms. For Keith, the ALEKS translations were sufficient for meaning making and thus allowed him to understand and compute the mathematical problem. He stated that on occasion he searched for meaning with an online translator:

> *A veces uso el [online] traductor así, pero no es mucho. Es que el traductor online casi siempre me traduce pero palabras comunes del Inglés, pero palabras así como, como se dijera o sea, propia a las matemáticas, esas casi no la traduce bien.* [Sometimes I use the [online] translator as well, but not

> too much. The reason is that the online translator, almost always translates common English words, but words, well, so to speak, mathematical words, those are hardly translated correctly.]

Keith's deficiency in academic mathematical literacy was an obstacle for meaning making of mathematical terms with an online translator. Keith felt sociocultural pressure to learn English, and as such he kept ALEKS in English for a majority of the time. However, the academic literacy deficiency obstacle influenced his continued use of the ALEKS translation capabilities, which was evident in Keith's total time spent on ALEKS.

Keith logged into ALEKS a total of 131 hours and 35 minutes. Figure 5.5 depicts Keith's learning trajectory terminating at 65% mastery of the total topics for this class, meaning he mastered 271 topics. Figure 5.5 illustrates that Keith's initial assessment of his pre-calculus prior knowledge was in a learning state that contained 33 topics, or 8% of the total number of topics. Keith steadily increased his mastery of the pre-calculus topics until he reached almost 300 topics, at which point Keith ceased working on ALEKS and settled for a grade of C for this course.

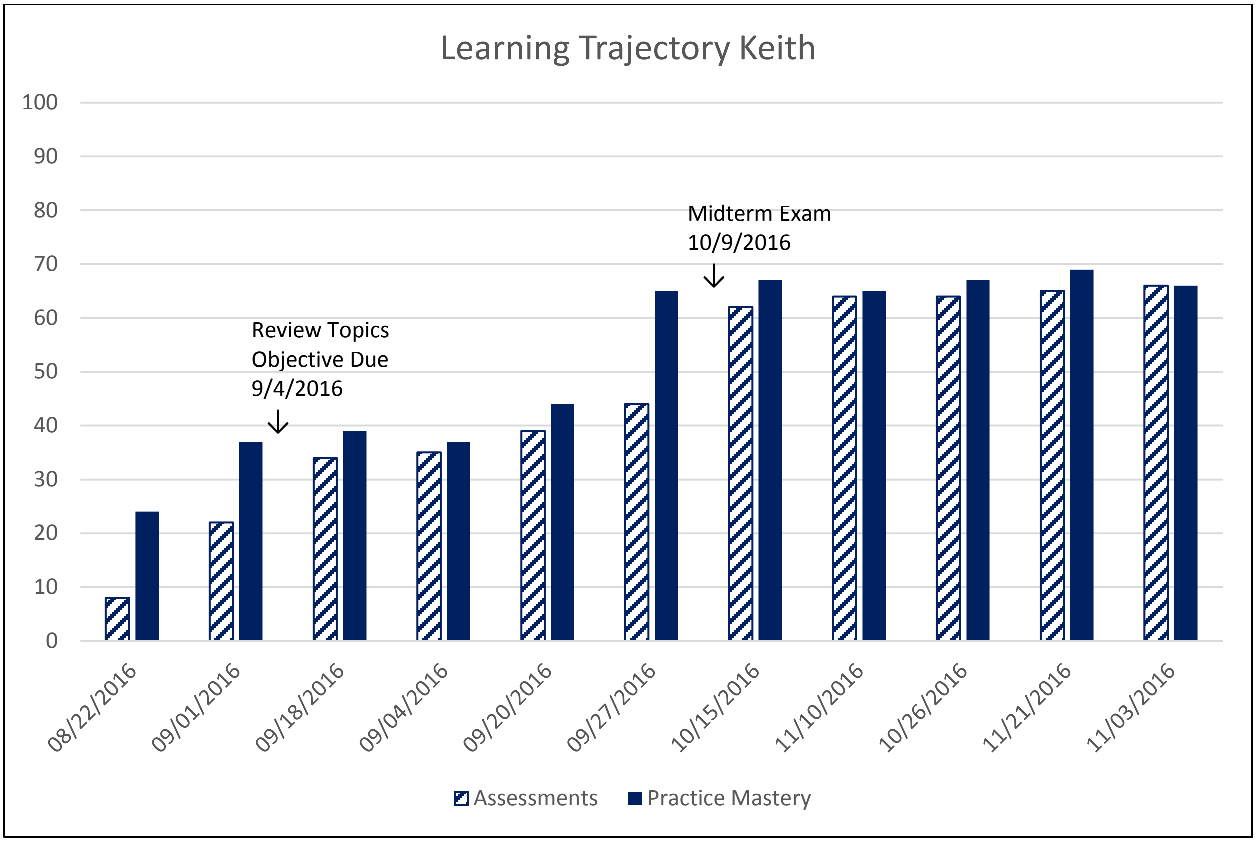


Figure 5.5. Learning trajectory for Keith showing the percentage of the number of topics mastered on his assessments (striped bars) and the percentage of the number of topics completed after each assessment (solid bars).

Susi. Susi identified herself as a Hispanic/Latina and Spanish-dominant emergent bilingual who attended elementary and middle school in Mexico. During her eighth-grade year, Susi's mother moved the family to Florida, where Susi found it very difficult because she did not speak English and her teachers could not understand her and did not speak Spanish. After three months Susi and her family returned to Juarez, Mexico where she finished her eighth-grade year. At that time, her family moved to El Paso, Texas where she was enrolled in ESOL classes at a local high school.

In El Paso, Susi was placed into ESOL math classes where she felt more comfortable because her teachers spoke Spanish and she was provided with a Spanish translator. Susi was able to ask the translator questions, and they would provide her with immediate translations. These bilingual math classes also provided students with a pamphlet where the problems were translated into Spanish. Susi read the pamphlets to make meaning of the mathematics and completed most of her first mathematics class in Spanish because of the pamphlets. She took fully monolingual English math classes in high school: Algebra II in her junior year and Pre-calculus her senior year.

Susi compared the bilingual high school math classes to her current online ALEKS pre-calculus course when she stated: “it was a bilingual class kind of like this [ALEKS pre-calculus], where the teacher spoke Spanish and I had a translator with me, so that helped a lot.” Although the online course offered at the university is not officially designated as a bilingual course, Susi, like many of her peers, considered this course a bilingual course. She read in the syllabus that the ALEKS program could be translated into Spanish and she immediately thought this would be helpful. She likened the ALEKS translation capabilities to the human translator who she’d had in her high school bilingual class.

Previously, while at the community college, Susi had taken an online pre-calculus class utilizing an online interactive educational system that does not provide formative, diagnostic assessments nor a learning path. Due to Susi’s lack of mathematical academic literacy, she was not able to pass the course. She felt that ALEKS was much more helpful, in particular with word problems wherein her academic language proficiency became an obstacle. Susi utilized the translation capabilities of ALEKS for mathematical terms. She struggled to make meaning of terms like “2 more than” or “3 less than” or “two times more than.”

When Susi encountered a word problem in which she did not understand a certain mathematical phrase it barred her from making meaning of the translation; hence, she searched the internet for Spanish-language videos.

> I look at…, on word problems I'll look at…, if I see what the problem is about then I look it up online, and then I look it up in Spanish if I have too, just so I make sure I understand it before I can go answer anything…

Susi searched for Spanish language videos to understand the explanations and register in which the word problems was written. She made cognitive connections between the language and the mathematics to understand what procedure or formula was required to perform the computations in the word problem. Susi stated:

> I do look for Spanish [videos] yes, when it's a word problem like if it's a, if it's a concept that is, that is in a word problem I look at it in Spanish because they will use the term they are using in the word problem and then I can relate it.

Susi utilized culturally relevant videos to connect the English register to the mathematics, thus creating mathematical biliteracy in a culturally relevant manner.

Susi averaged fourteen and a half hours per week working on the ALEKS program and accumulated 164 total hours for the entire semester. Figure 5.6 depicts Susi's learning trajectory throughout the fall 2016 semester, during which she earned a B for the course. As was the case with previous Funneled informants, Susi's learning trajectory illustrates a continual increase from one knowledge check to the next, on her way to mastering 65% of the total topics for the course.

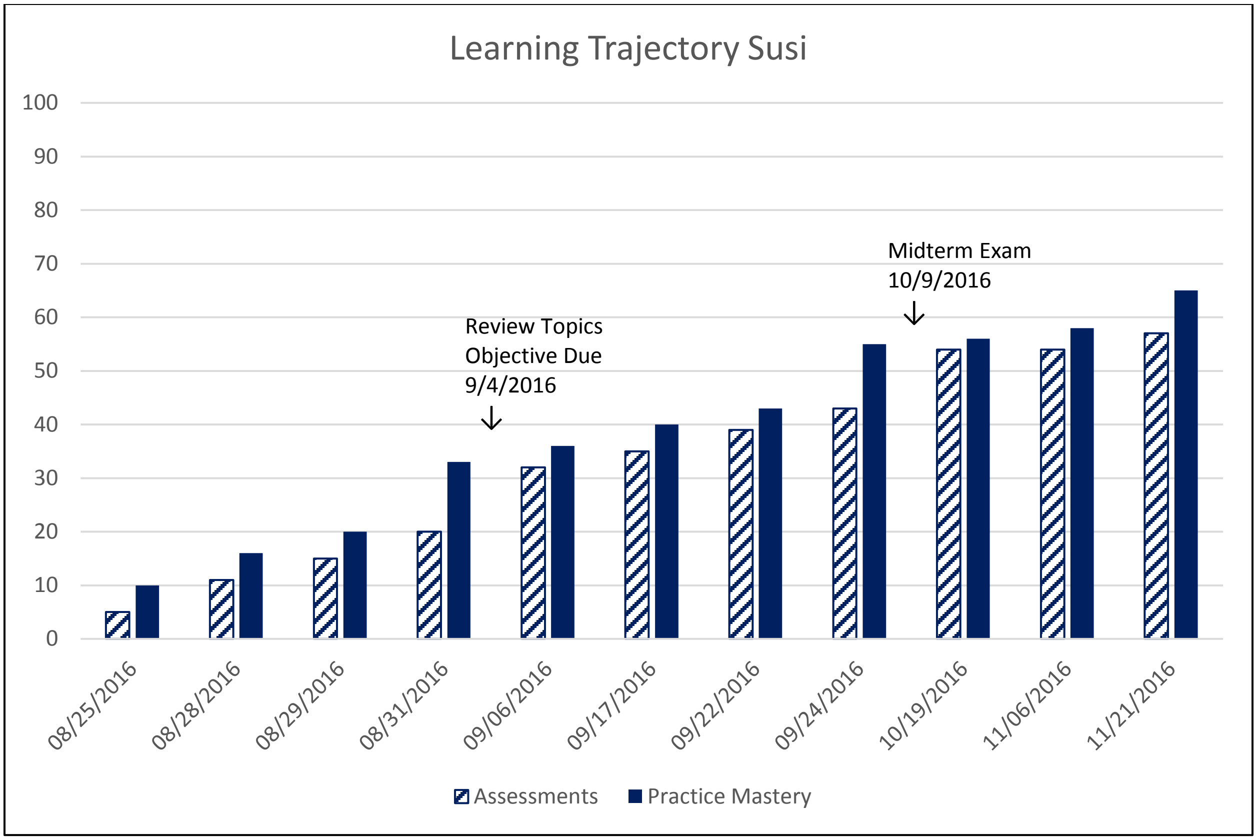


Figure 5.6. Learning trajectory for Ray showing the percentage of the number of topics mastered on his assessments (striped bars) and the percentage of the number of topics completed after each assessment (solid bar).

Summary of Funneled informants. As students in a fully online pre-calculus course, these Funneled informants began this course utilizing ALEKS to learn the mathematical topics that encompassed this pre-calculus course. Regarding their educational backgrounds, two Funneled informants migrated to the United Stated in middle school while the rest completed their K12 education in Mexico. Funneled informants constructed a foundation of mathematical knowledge that they mentally accessed in Spanish, the language of instruction for basic arithmetic. When they encountered the first of two tensions, encountering unfamiliar Spanish dialects or translation, these Funneled informants transformed their digital activities to mediate the translation capabilities of the software and online translators for meaning making of English

register and mathematical lexicon. When this tension persisted within this activity, and they could not comprehend the mathematical topics, they again transformed their digital activities to include searching online for culturally relevant videos.

The Funneled informants developed agency in their learning by creating a bilingual digital learning environment through the translations of the instruction and explanation and the use of culturally relevant videos. They wanted to create cognitive connections between their mathematical prior knowledge acquired in Spanish and future topics that they would encounter in English. Therefore, they networked these multiple activities to not only create a bilingual digital space but also to maintain their learning of English, one of the tensions these Funneled informants encountered. Through emersion and constant comparison of the data provided by the Digital and Funneled informants the themes and digital strategies of how emergent bilinguals engaged in an online pre-calculus course developed and crystallized.

Analysis Process

Data was gathered from one demographic survey, two self-efficacy surveys (fall and spring 2016 semesters only), 7-8 weekly course forum questions, daily logs with screen shots, email interviews with focus groups, and face-to-face interviews with six Funneled informants in an attempt to understand the digital practices of emergent bilinguals participating in an online pre-calculus course. By engrossing myself in the data, I continuously explored the digital meanings of the class forum posts and email interviews in order to tie this information back to the research questions.

Data analysis in an embedded design is an interactive approach in which qualitative data will be analyzed before, during and after the supplementary quantitative data has been analyzed. Through reflection, comparison and interlacing of the data throughout the four phases of this

study, four themes emerged from the data: the importance of learning English, translating software to Spanish and using online translators; meaning making; and students creating a bilingual digital learning environment.

Phase One. Two self-efficacy surveys were utilized during the 2016 spring and fall semesters, using Qualtrics. A link to each survey was posted in the ALEKS course forum. The pre-surveys were posted in the third week of each semester and the post-surveys were posted during the final weeks of the semester. The first survey, Mathematics Self-Efficacy Scale (MSES), measured a participant's self-efficacy in mathematics and the second survey, Mathematics and Technology Attitudes Scale (MTAS) measured their confidence in doing mathematics and working with technology in a mathematics course. Post self-efficacy surveys were completed by participants in phases three and analyzed to find an association between their self-efficacy and translating of the software into Spanish.

Phase Two: Focus groups and email interviews. Email interview questions were developed to elicit deeper insight into participants' digital practices than was reported in the course forum (Appendix L). As part of the email interviews, daily logs (Appendix M and N for a sample of a daily log) were developed in which focus group participants could record the time they logged into and out from ALEKS, the number of times they translated the software into Spanish, if they used an online search engine, and how many times they clicked on the explanation button. If participants searched online for tutorial material, they were asked to take a screen shot of what they found and send it to the researcher. These logs provided one source of information used to triangulate, and thus ensure the trustworthiness and credibility, of the data in this study; other sources included forum posts and interviews.

Course forum questions were posted onto the ALEKS "class forum" section to elicit participants' digital experiences while engaging with the software. The class forum posts were recorded onto Excel files, in a password protected laptop, where I could engross myself in the data as rapidly as possible. Examples of the class forum questions along with focus group responses are listed in Table 5.2. Table 5.2 displays the forum questions posted by the researcher/instructor in bold at the top of the table. Participants are listed in the first column on the left, and their responses are located below each question. All responses for the course were recorded into an Excel file and then study participants' responses were identified and exported to a separate Excel file. Each course forum response was deleted approximately one week after the forum question was posted for purposes of confidentiality and trustworthiness.

Table 5.2.

Example of course forum posts.

	How did you feel about your initial assessment in the program ALEKS?	**If you changed the ALEKS program into Spanish, explain how this affected your understanding of the topics.**	**Did you change the midterm to Spanish?**
Participant 1	This initial assessment was a little bit long and challenging but Math are coming back to my brain. It is like a language that if you don't practice you will forget about it. Support videos found in YouTube helped me so I could refresh myself in Algebra. I find ALEKS Learning Program pretty professional and dynamic. I still do not get used to the mandatory 8 hours a week rule. Last week I got everything done before the due date and still received the class drop warning from you, but now I am understanding how that rule works.	I change it when I don't know the meaning of a word or concept because all my previous algebra and math knowledge is in Spanish, but I try to keep it up in English.	I do changed the language setting to Spanish in two questions just to make sure I was understanding concepts correct. My first language is Spanish.
Participant 2	ALEKS is a great program for students whose greatest suit may not be math. The fact that you get to work at your own pace and understanding really ensures that you're prepared for your next math course.	I have not change the language but since Spanish is my first language it's nice to have the option in case I don't understand something	I did not change the midterm exam Spanish
Participant 3			En algunas preguntas si lo cambie …solo lo cambien a español en algunas preguntas

Initial content analysis of the class forum posts produced open coding where I, as the researcher, expressed what I thought each participant was trying to articulate (see Table 5.3). Table 5.3 depicts the course forum questions in bold in one column and the open coding of the participant's response in the second column. The bottom row in Table 5.3 indicated the codes that emerged from the open coding and questions to aid in the development of future forum questions or email questions. The ensuing step as the researcher was to navigate my analysis from open coding to axial coding to produce categories and themes (Lichtman, 2013). Two themes, meaning making and translating the software to Spanish, emerged from the axial coding of the class forum posts during this phase.

Table 5.3.

Open coding example.

	If you changed the ALEKS program into Spanish, explain how this affected your understanding of the topics.	**Open coding**	**Did you change the midterm to Spanish?**	**open coding**
Participant 1	I change it when I don't know the meaning of a word or concept because all my previous algebra and maths knowledge is in Spanish, but I try to keep it up in English.	Changed the software in order to make meaning of vocabulary...He wants to keep the software in Spanish, why?	I do changed the language setting to Spanish in two questions just to make sure I was understanding concepts correct. My first language is Spanish.	changed software to Spanish to understand concept
Participant 2	I have not change the language but since Spanish is my first language it's nice to have the option in case I don't understand something	Did not change software to Spanish, why?	I did not change the midterm exam Spanish	did not change software
Participant 3			En algunas preguntas si lo cambie …..solo lo cambien a español en algunas preguntas	changed software for a few problems,
CODES		Not all Digital informants translated the software. Why?		More participants translated the Midterm, to understand the concepts. But why only a few problems?

***Translating ALEKS*.** One key feature of the ALEKS program is that all practice problems, knowledge checks, explanations and the interface pages can be translated into

Spanish. Two studies conducted by Casas et al. (2011) and Wang and Liao (2011), have shown that translating mathematical software into a student's native language can benefit students mathematical learning. Participants mediated translating ALEKS in order to obtain the object of their activity which was to make meaning of the ALEKS explanations and mathematical terminology. Two codes, as supported below by demonstrative quotes, emerged as the reason for translating the software:

1) To make meaning of one or two mathematical terms or English vocabulary: "I change it [ALEKS] when I don't know the meaning of a word or concept because all my previous algebra and math knowledge is in Spanish, but I try to keep it up in English." and
2) To understand the concepts and explanations: "Sometimes I change language to Spanish or English because sometimes I do not understand very well the questions In English so I change it [ALKES] to Spanish."

These two strategies were the object that motivated emergent bilinguals to construct an activity for meaning making in this online pre-calculus course (Figure 5.7).

Figure 5.7 depicts the activity system developed to explicate emergent bilinguals' mediation of the translation capabilities in ALEKS to make meaning of English vocabulary and mathematical lexicon while working in this online pre-calculus class, and their roles in this community. Figure 5.7 shows the triangular diagram developed by Engeström (1999) to fully articulate the complex actions of a subject within a sociocultural educational environment. The subjects, emergent bilinguals, followed the course procedures as outlined by the course syllabus which encouraged them to translate the software. They translated the software to make meaning of one or two mathematical terms or to understand the English register of the explanations.

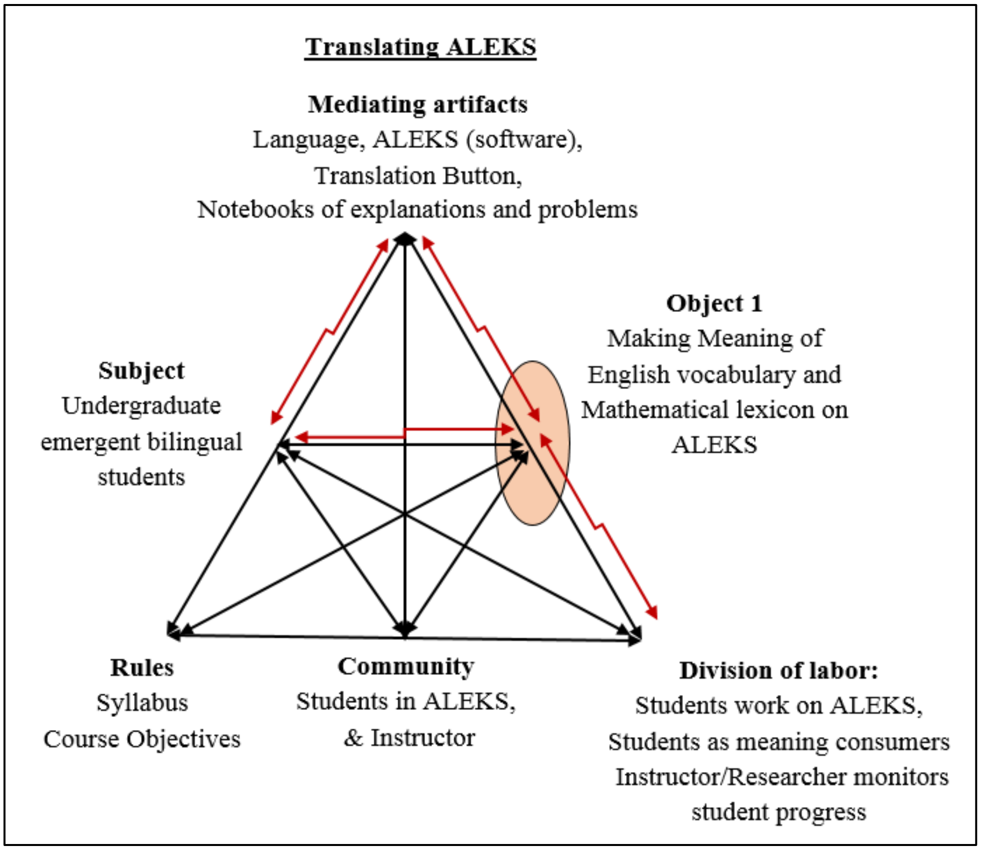


Figure 5.7. Activity system for translating ALEKS with tensions (red arrows).

Figure 5.7 displays the six components of Engeström's activity system with arrows to indicate the interactions between each component that were developed for this online pre-calculus course. The red lightning bolt-like arrows represent the tension that emergent bilinguals encountered due to their encounter with unfamiliar Spanish dialects or translations. The experiences and activities of several Digital informants are outlined next.

Gracia echoed many of the digital practices of the emergent bilingual participants who translated ALEKS into Spanish when she stated:

> *Yo si cambie el lenguaje a español…Para mí que se mas español que inglés es de mucha ayuda. Si estuviera solo en ingles no le entendería a todo. Estoy*

> *tomando clases de ESOL* [I did change the language to Spanish…For me, that I know more Spanish than English it is much more helpful. If it were only in English I would not understand everything. I am taking ESOL classes.]

Like Gracia, participants who translated the software into Spanish were concerned that they would not complete the ALEKS topics if they continued with the software in English. They worried that they would not understand what was being asked of them, so they translated the software, especially when taking the midterm exam. When the translation of ALEKS did not provide adequate assistance for these participants, they utilized their digital literacies to make meaning of this course.

The academic language domain of this online pre-calculus course required emergent bilinguals to negotiate new meaning making practices for mathematical terminology that they had previously negotiated in Spanish monolingual math courses. Likewise, they were making meaning of English vocabulary that was obstructing their understanding of instructions and explanations. Instead of making meaning of mathematical vocabulary and syntax through social interaction, conjectures, presenting explanations and constructing arguments (Moschkovich, 2007; Gee 2007; Gutierrez, 20002) participants utilized internet dictionaries, internet searches, and translation of the ALEKS software.

Susi translated ALEKS when she encountered the mathematical phrase “two times more than.” She did not understand how to transform this phrase into a mathematical formula when she read this in English; hence she translated the software to make meaning of the phrase. Susi found that translating the software did not help her with the phrase, so she clicked on the explanation button. Susi reported that the Spanish translation of the explanation was confusing

and of little help. At this point, she altered her action from translation to finding culturally relevant videos. She found a Spanish language Khan Academy video that allowed her to make meaning of this mathematical phrase. These strategies were reported by fellow emergent bilinguals when they encountered translations that were confusing or in a different Spanish dialect. These tensions and contradictions lead to a transformation of their action for meaning making.

Emergent bilinguals brought to this online class a systematic process for creating digital literacies derived from their experiences with video games, texting, Facebook, and internet searches (Gillen, 2014; Gilster & Glister, 1997). Utilizing multimedia arenas is the essence of the definition of digital literacy provided by Gilster's and Gilster (1997), i.e., "the ability to access networked computer resources and use them" (p. xii). More recently, digital literacy has been defined as the practice of communicating, relating, and being involved in creating new ways of mixing multimedia tools to accomplish meaning making (Jones & Hafner, 2012). Emergent bilingual participants in this study were actively developing "hypertext minds" (Prensky, 2012), toggling from graphics to text, accessing data at random (random access), and in this online pre-calculus course, toggling from Spanish to English. Hence, emergent bilinguals in this study created ways to utilize digital media for meaning making (Figure 5.8), summed up in the participant quote: "*Si no entiendo el significado la palabra la traduzco a español usando google translate*" [If I don't understand the meaning of the word I translate it to Spanish using Google Translate].

Online translators. Participants were more apt to use the internet as a multimodal tool for meaning making, instead of reading text or a paperback dictionary as Marco did. Also digital natives, these emergent bilinguals utilized Google translate as a multimedia tool to make

meaning of mathematical terms. Google translate allowed them to read the definition as text. They could then click on hyperlinks for word origins to make connections to Latin-based languages or to listen to the word in English. Google Translate also provided a mathematical definition if one was available. Understanding digital media allowed emergent bilingual participants to make meaning of terms that were impeding their comprehension of a problem or explanation.

Figure 5.8 depicts the activity system that was developed to explicate emergent bilinguals' migration to use online translators. The subject and rules in this activity system remained constant for both activity systems (Figures 5.7 and 5.8). Emergent bilinguals were mediating online translators to find meaning of English vocabulary and mathematical lexicon as they did in the translating ALEKS activity system (Figure 5.8). Encountering unfamiliar Spanish dialects or translations, depicted in Figure 5.8 by the red arrows, signified a tension that motivated these emergent bilinguals to a new digital activity. Within this activity system, the subjects' roles also morphed into digital consumers and biliterate learners to accommodate a larger digital community.

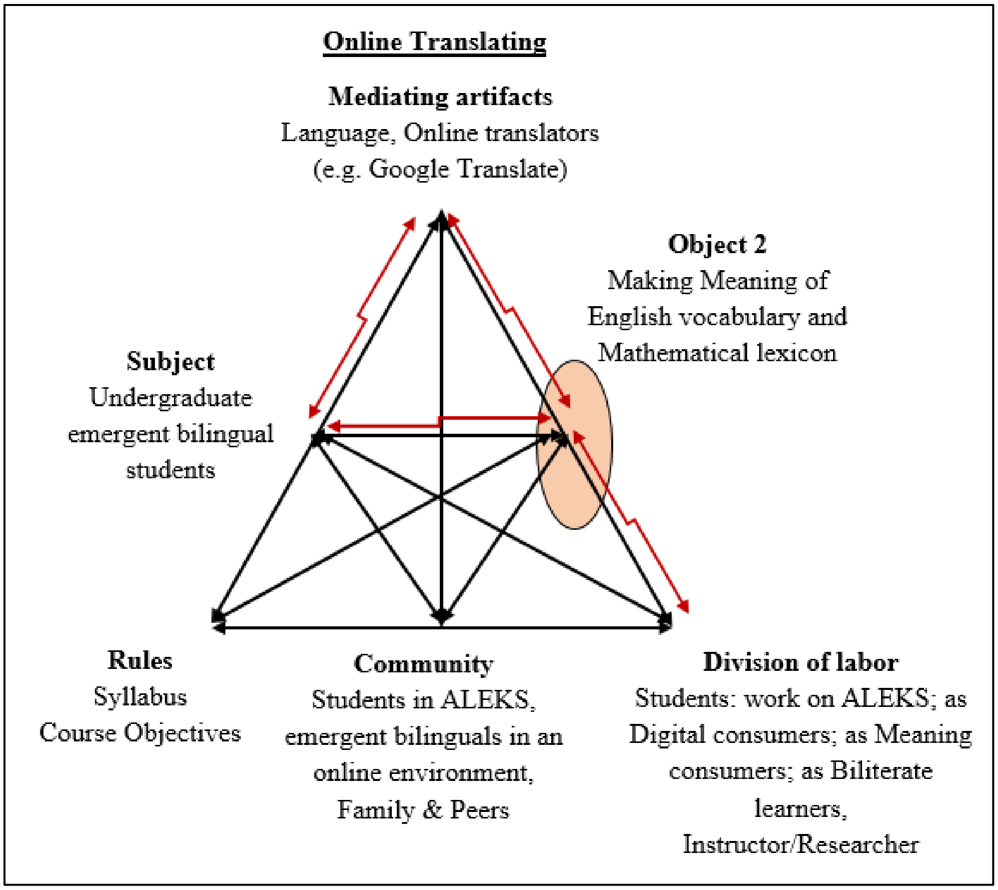


Figure 5.8. Activity system for the use of online Translators with tensions (red arrows).

As digital natives, emergent bilinguals do not learn sequentially; rather, they are continuously searching for information and cultural interpretations in a multimedia environment. If a dictionary or Google Translate proved ineffective or insufficient for making meaning of mathematical terms, participants searched ALEKS for possible solutions. These participants, through digital strategies such as random clicking and looking for help buttons or hyperlinks, found that they could translate ALEKS into Spanish.

Echoing the thoughts of the focus group, Marco stated:

"I did change the program to Spanish because I can more relate all the topics in Spanish. Sometimes I see in the topic and I don't understand what I need

> to do. So, when I changed to Spanish I can understand all the instructions and I start to work."

In this case, it was not that Marco was negotiating the meaning of a mathematical term, but making meaning of the instructions and explanations in order to perform the mathematical operations. Participants, like Marco, found themselves attempting to make meaning of instructions and explanations. Hence their digital strategies shifted from meaning making of one or two mathematical terms to understanding instructions and explanations. They wanted to make cognitive connections between the language of instruction and the mathematics. Understanding the instructions was especially important during the high-stakes midterm exam.

High stakes exam. The midterm exam contained fifteen problems. Three Funneled informants Marco, Gracia, and Keith, translated the entire exam into Spanish. Among participants in the Digital informants group, 40% stated they translated only two or three problems from the midterm exam while 27% of them translated the entire test.

Fernando, a Digital informant in the spring 2016 course, was among the group who reported only translating a few questions on the midterm. Asked to explain why he translated only a few problems from the midterm exam into Spanish, Fernando, stated that he wanted to confirm his understanding of the instructions: "I do changed [sic] the language setting to Spanish [for the midterm exam] in two questions just to make sure I was understanding concepts correct. My first language is Spanish." Fernando voiced the thoughts and emotions of the focus group participants, i.e. that they are Spanish-dominant emergent bilinguals, in saying "my first language is Spanish." Also inferred from this statement is Fernando's ideology of the importance of learning English by reporting that he had only changed two questions. Like Fernando, Marco responded to this forum post in English to affirm his belief that knowing English was important.

Another Digital informant from the 2014 fall semester, Oscar, stated: “I changed midterm to Spanish because one of the topics, I learned it in Spanish, but I was getting confused when translating it to English.” In the high-stakes atmosphere that is an exam, Oscar stated that he was confused and this was not acceptable for an exam. The confusion may have simply been exam anxiety; however, he felt more confident when he translated the exam problem into Spanish in order to make a cognitive connection with the practice problems he had learned in the same language.

The experiences of Oscar and Fernando offered an insight into their digital experiences of connecting their prior knowledge to future topics. Digital informants felt strongly that they had to make a cognitive connection between mathematical prior knowledge they had negotiated in Spanish, and the ALEKS topics they were learning in English, as well as with future math classes. Fernando and Oscar, like many participants, did not translate the software into Spanish for the entire semester, because they felt it was important that they improve their English proficiency in mathematics.

Phase three: Content analysis. In phase three, data from class forum posts continued while data from email interviews was collected and analyzed. Data analysis to focus the data into the previously mentioned themes was conducted through an inductive process and by constantly comparing email interviews with class forum posts. The themes that emerged from this process were: meaning making; translating software to Spanish and using online translators; the importance of learning English; and students creating a bilingual digital learning environment. The first two themes, meaning making and translating software into Spanish and using online translators, were continually supported by the email interviews. Another overarching theme, and important related tensions, that emerged in this phase was the importance of learning English.

Tension One: Encountering unfamiliar Spanish dialects or translations. Forty percent of the Digital informants partially translated the ALEKS software. They either translated the instructions on one or two problems to make meaning of the instruction, or they translated to make meaning of mathematical terminology. They translated portions of the midterm exam in order to feel confident that they understood the instructions or to ensure that they calculated the problem correctly. Again, they did not translate the entire midterm exam, only a few problems.

One Digital informant, Alvaro, was educated in Mexico before enrolling at UTEP, reported that the Spanish translation provided by ALEKS confused him: "*Como que el lenguaje estaba poquito diferente, y me confundía*" [Like the translation language was a little different and it would confuse me]. Alvaro found the translation to be different, either the dialect or the translation was unfamiliar to him. This tension was supported by several Funneled informants; hence, a secondary activity system was developed to explicate their activity of searching for online translators.

The activity system for utilizing online translators was a reaction to the language tension Digital informants encountered when clicking on the translation button in ALEKS. Participants mediated online translators for the object of making meaning of English vocabulary and mathematical lexicon. However, they found that translators like Google Translate were sometimes out of context or not culturally relevant.

Tension two: Importance of learning English. Thirteen percent of the Digital informants (2 out of 15) reported that they translated ALEKS throughout most or all of the semester. I inferred this to be an aspect of the second tension: the importance of learning English. Gracia and Marco emphasized that when working on mathematics their cognitive recognition of these topics was in their native language, Spanish. Their forum posts reflected their fellow Digital

informants' posts, wherein students stated that they translated the software to make meaning of instruction and explanations. Although Marco and Gracia were the only two Digital informants to translate ALEKS throughout the semester like many of the Digital informants, they felt it was important to learn English.

Emergent bilinguals felt that if they learned a topic in Spanish they would not be able to cognitively connect this topic to future topics or future courses taught in English. Omar, a Digital informant from the fall 2015 semester, felt that if he studied pre-calculus topics in Spanish, it would negatively affect him in future classes by requiring more time to mentally connect the Spanish prerequisite topics to a new English topic:

> "I try to do topics in English because I know in the future that I will be using this specific concepts so understanding them in English will make my comprehension way more easier. If I study them in Spanish I don't spend that much time in the topic as in English but in my mind its doing more work because later I will need to do them in English."

Although Omar and other participants stated that they would mentally compute fundamental arithmetic operations in Spanish, they did not feel confident that translating a topic into Spanish was beneficial for their future. They worried that topics learned in Spanish would not be mentally retrieved while calculating future topics or worse, that prerequisite topics learned in Spanish would not be cognitively connected to future topics.

Participants believed that learning mathematics in English was crucial to future classes as well. Anna was a Spanish-dominant emergent bilingual who was educated in Mexico until she enrolled at the university in the fall of 2014. She was acutely aware that future classes would be

face-to-face and the ability to create a bilingual digital space would not be available to her in these future classes:

> *… ya que de ahora en adelante todos los temas que aprenda en matemáticas serán en inglés y no tendría sentido aprender cosas en español que luego no me van a servir para clases posteriores ya que serán en inglés. Adicionalmente, quiero familiarizarme con algunos términos matemáticos en inglés para estar preparada para una clase presencial* […since from here on out, everything you learn in mathematics will be in English and it would not make sense to learn things in Spanish then it will not serve me well for future classes what will be in English. In addition, I want to familiarize myself with some mathematicians in English terms to be prepared for a face-to-face class].

In anticipation of future classes, Anna had strong opinions about the importance of learning English. She and her Digital informant peers recognized that attending a university in the United States meant that at some point their math and science classes would be taught in monolingual English classes. Therefore, their ultimate goal, i.e. Activity Theory outcome, was to learn mathematics in English while having fundamental arithmetic knowledge in Spanish. This amounted to learning mathematics in both languages.

Marco, who was a metallurgical engineering major, knew that most of his engineering classes would be taught in English. He felt ALEKS provided him an opportunity to learn English while also learning mathematics. When he created a cognitive connection to the mathematics in English he utilized the translations from ALEKS or his dictionary to make these connections. He had developed a bilingual digital space, through the use of online tutorials and videos in order to learn mathematics in both English and Spanish.

Marco indicated that he planned to return to Mexico once he attained his metallurgical engineering degree. Through Marco's sociocultural experiences, his mindset was that he would be more marketable, "more job worthy," if he was bilingual. Keith echoed these thoughts on the importance of knowing English as a career strength. Keith felt that being fluent in both English and Spanish was like having two people doing the work for one, "vale por dos uno." Therefore, understanding mathematics in both languages was crucial to career and economic success. Participants in this study were in agreement with Marco's and Keith's attitudes that learning English was important for their short and long term goals.

In a face-to-face interview Gracia articulated how she felt she had no other option but to learn English:

> *El matemática las vamos aprender porque es un idioma que tenemos que hablar, o sea…venimos a los estados unidos tenemos que aprender la idioma inglés* [We are going to learn mathematics in English because it is the language that we have to talk, or... We come to the United States so we have to learn the English language].

Emergent bilinguals felt that in a country, where English is considered the national language, there is a glass ceiling for non-native speakers that can be broken only through language literacy and more importantly, in a technological world, through digital literacy (Bates, 1997; Kalantzis & Cope, 2012; Keister, Vallejo, & Borelli, 2015; Vallejo, 2009). Gracia continued:

> *Entonces obviamente pues tenemos que aprender matemáticas también igual en el mismo lenguaje* [Then obviously we have to also learn math in the same language].

Gracia believed that upward social mobility was available for emergent bilinguals who learn the *lingua franca* and digital literacies (Bates, 1997; Keister, Vallejo, & Borelli, 2015; Vallejo, 2009). Emergent bilinguals felt obligated to learn mathematics in English adding to the “standard language ideology” that proper mathematical literacy justified social and political upward mobility (Milroy & Milroy, 1985).

Culturally relevant videos. Emergent bilinguals translated the software and utilized online translators to make meaning of mathematical vocabulary and English register in the explanation and instructions. However, the unfamiliar Spanish dialects or translations they encountered became an obstacle to their comprehension of the mathematical topics. The high stakes of the midterm exam amplified their need to make mathematical cognitive connections to the language of instruction. The importance of learning English in a mathematics course was also a tension that motivated emergent bilinguals to transform their actions yet again.

In an attempt to connect the mathematics with their native language, emergent bilinguals searched online for tutorial videos (see Figure 5.9). Emergent bilinguals searched for Spanish-language videos on YouTube and through Khan Academy. Figure 5.9 diagrams how emergent bilinguals with the same rules mediated online videos and tutorials to create a digital community, one in which they became meaning consumers and producers as well as biliterate learners. The red arrows in Figure 5.9 indicate the persistent tensions emergent bilinguals encountered in this activity system.

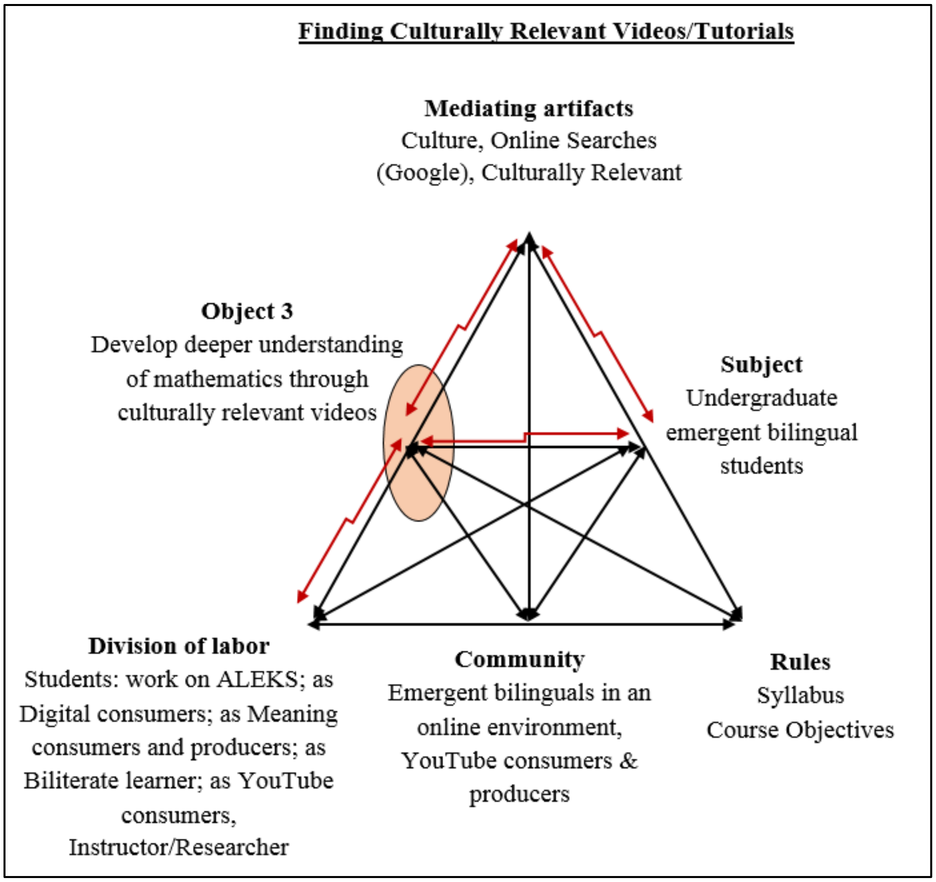


Figure 5.9. Activity system diagram of finding culturally relevant video/tutorials with tensions (red arrows).

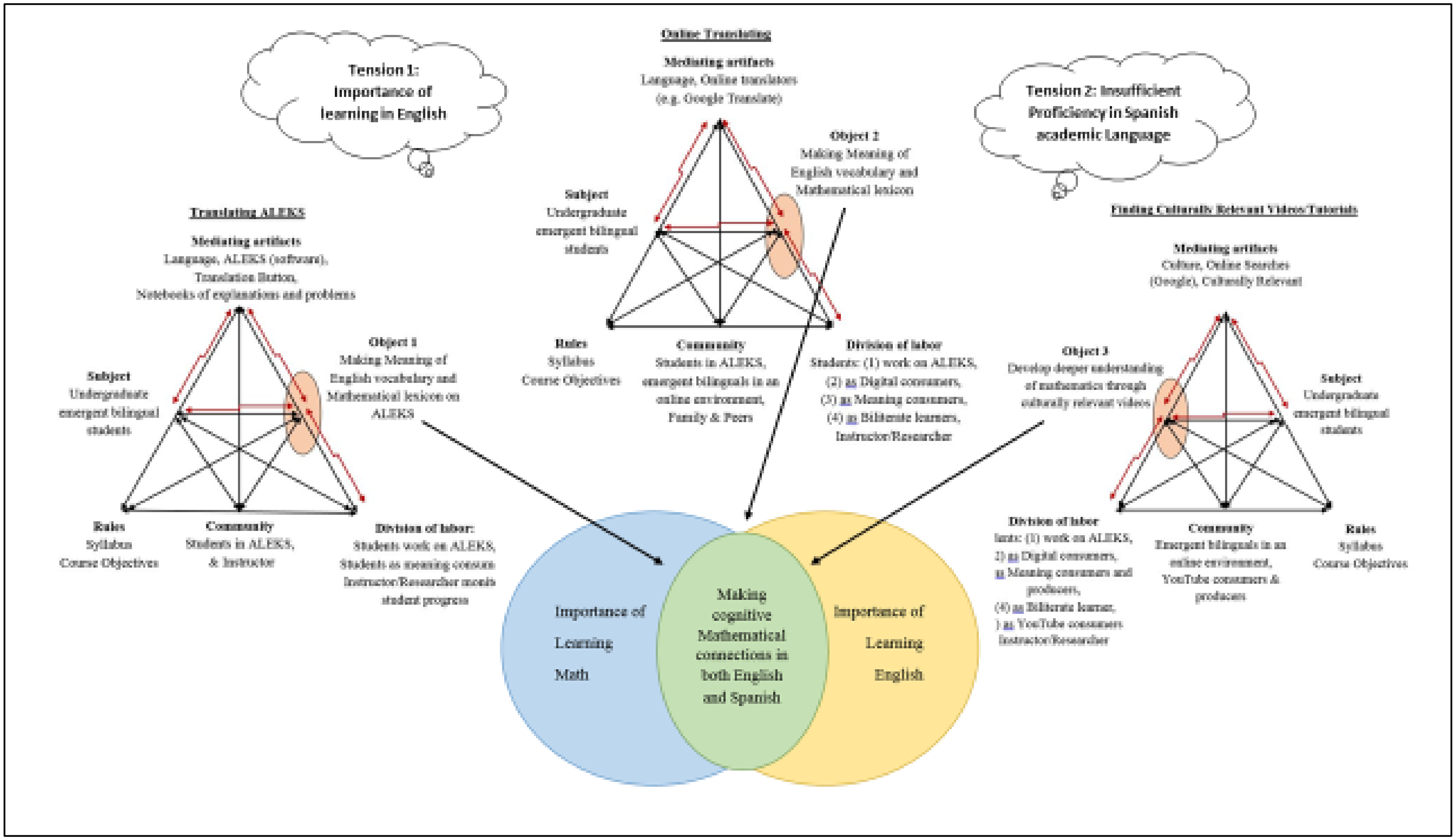
Emergent bilinguals' misunderstanding of Spanish dialects or translations once again was an obstacle in comprehending certain videos. They were able to find tutorial videos that were in a dialect they understood and that provided instruction in a culturally meaningful way. This tension did not lead to this transformation of the activity. This activity was a response to emergent bilinguals' tensions of the importance learning English and making mathematical connections in both languages. Emergent bilinguals were creating digital literacies as well as mathematical literacies when they mediated these three activities.

A network of activity systems. The tensions emergent bilinguals were experiencing motivated them to combine their digital practices into a complex network of meaning making

and producing activities. Figure 5.10 diagrams the network of activity systems emergent bilinguals employed in this study to learn mathematics as well as English. It was of great importance to the Digital informants that they learn English while simultaneously comprehending the mathematics. Figure 5.10 displays the objects of the three activity systems merging together for the final outcome in response to the two tensions, represented by thought clouds. By employing three activities, emergent bilinguals became meaning consumers and producers.

Emergent bilinguals translated the software and utilized online translators for meaning making, depicted by the left and top activity triangles in Figure 5.10. They then incorporated culturally relevant videos into their digital actions to produce meaning of the mathematics, indicated by the activity triangle at the right in Figure 5.10. Digital natives are producers and consumers of multimedia technologies and they create meaningful digital spaces for agency (Prensky, 2001). The emergent bilinguals in this study weaved together three activities of meaning making to produce meaning of mathematical concepts in English and Spanish in a complex digital space.

Figure 5.10. Network of all three activity systems.



Their final outcome, or goal, was to make cognitive mathematical connections in both English and Spanish. This was accomplished by creating a bilingual digital course through the use of their digital practices and developing mathematical biliteracy.

Phase four: Connecting to the research questions. Through constant comparison of the data in its entirety, the themes previously discussed connected how digital native emergent bilinguals engage in an online pre-calculus class. Each theme was represented by an activity system to describe the digital practices for the Digital informants. Two themes that emerged in phase four were the importance of learning English and students creating a bilingual digital learning environment. In the tradition of an exploratory approach, these themes were analyzed in relation to the research questions to ensure that each contributed meaning to the study.

Research Question 1: How do undergraduate English Language Learners engage with an online math course? The first research question was developed to describe how emergent bilinguals engage in an online pre-calculus course. Participants engaged in translating the software to make meaning of mathematical vocabulary and to understand explanations. They searched the internet for videos that were in their native language and that were culturally sensitive to their previous monolingual Spanish education. The first research question contained two sub-questions designed to explicate how emergent bilinguals engaged with an online mathematics course.

Research Sub-Question 1A: How do English Language Learners make meaning of mathematical terminology using digital practices? The first sub-question was designed to describe emergent bilinguals' meaning making digital practices. Emergent bilinguals translated the ALEKS software, used Google translate and/or found videos in their native language that they could integrate into their learning of mathematical terms. For some participants, translation

of the software was sufficient. As Angelica, a Digital informant from the 2014 fall semester stated, “I changed it to Spanish because there were terms and concepts that I already knew but got confused when going over them in English.” The multimodality of these digital learners allowed them to utilize several digital practices in parallel, as in having several screens opened at once. Jaime, a Digital informant from spring 2016, reported that he often worked on ALEKS while simultaneously having the television on, listening to music on earbuds, and surfing the internet.

Research Sub-Question 1B: How does language meaning making with an intelligent tutoring system improve emergent bilinguals’ progress with an intelligent tutoring system? Utilizing the translation capabilities of the software along with step-by-step explanations allowed Digital informants to complete practice problems and knowledge checks to show mastery of these topics. Marco stated: “When I changed to Spanish I can understand all the instructions and I start to work.” Marco felt that when he translated the software to Spanish he not only understood the instructions better but was able to complete more topics. He felt that his time would not be lost on reading and re-reading the instructions and explanations in English, his second language.

Time spent on ALEKS. Through descriptive statistics of the learning progress of emergent bilinguals and their English-dominant peers, it appeared that creating a bilingual digital space did have an effect on Digital informants’ time spent on ALEKS. Oscar expressed how his time on ALEKS was affected by his meaning making strategies:

> *El dominio de idioma ingles en ALEKS si determina el tiempo en ALEKS ya que unos temas por no saber que significan en ingles hace que tardes más, de por si hay temas que son complicados de entender llegan a complicarse*

> *más por no saber que te están pidiendo* [Mastery of the English language in ALEKS did determine the time on ALEKS because not understanding the meaning of some topics makes one take more time, there are some topics that are complicated and made worse by not understanding what is being asked of me].

Oscar's digital practices to make meaning of instructions and examples required more of his time on ALEKS, yet Oscar's time spent on ALEK was equivalent to the time spent on the program by English-dominant students who earned the same grade as Oscar (a, "B").

Figure 5.11 indicates that the total time spent on ALEKS in hours (vertical axis) by 12 Digital informant was proportional to 12 randomly selected English-dominant students who attained similar grades. English-dominant participants were selected through analysis of their demographic survey. They were also selected by the grades they attained in the course to directly compare with the 12 Digital informants. The red dotted line in Figure 5.11 depicts the time spent on ALEKS and grades for English-dominant students, while the solid black line depicts the time spent on ALEKS and their grades by emergent bilinguals. Analysis of Figure 5.11 shows that several emergent bilinguals, points 2, 3, 8, 9, and 12 did, in fact, require more time on ALEKS than their English-Dominant counterparts in order to attain an equivalent grade.

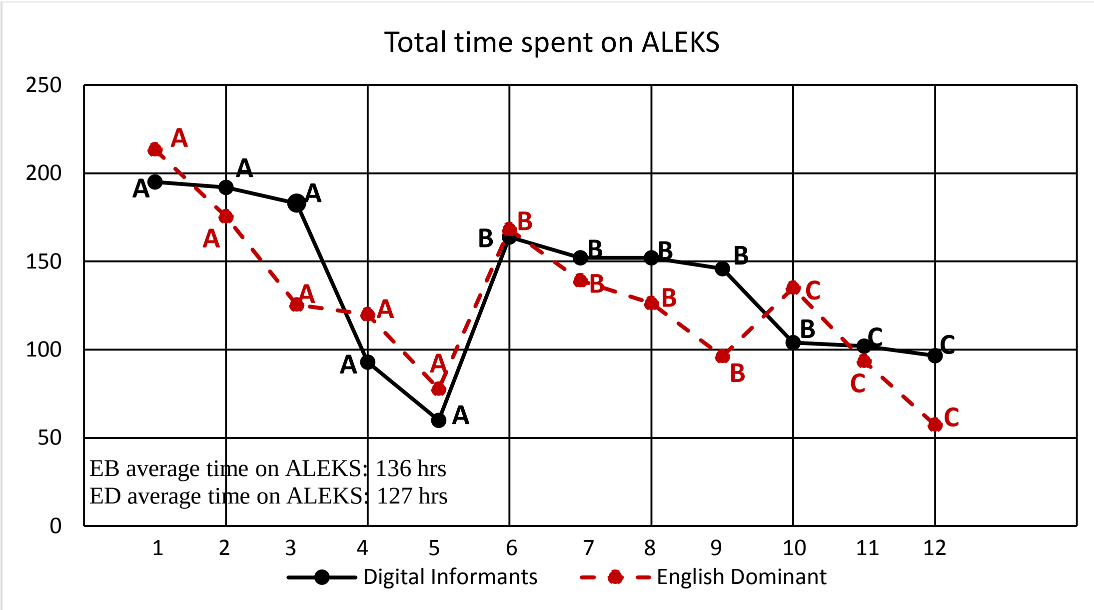


Figure 5.11. Total time spent on ALEKS by the Digital informants and English-Dominant students who earned equivalent or similar grades.

Learning Trajectories. Figure 5.12 is comprised of two charts; the first depicts the initial and final assessments for 12 Digital informants, while the second chart depicts the same information for 12 randomly selected English-dominant students with similar grades. A simple t-test was conducted for each group to compare the initial assessment with the final assessment. A statistically significant increase between the initial and final assessment was determined ($p < 0.01$).

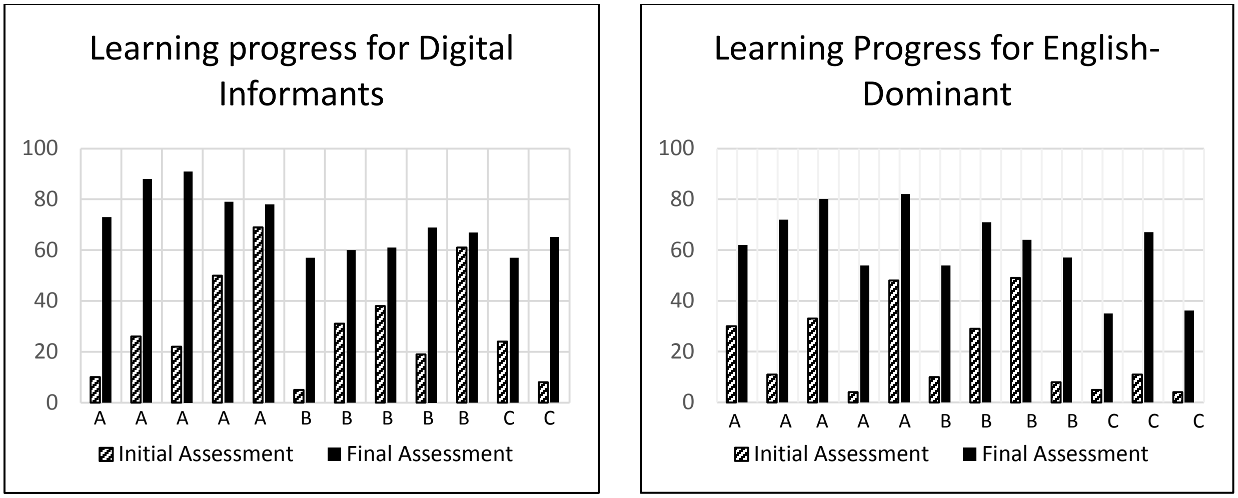


Figure 5.12. Comparison of Digital informants' and English-Dominant students' initial assessment and final ALEKS assessment. The vertical axis measures the percentage of topics mastered for each assessment.

Participants made cognitive connections between the topics practiced and future topics when they translated ALEKS into Spanish. Making these connections became increasingly important when students were required to complete the automatic knowledge checks. They had more confidence computing certain math problems in Spanish. Hence, when a high-stakes assessment such as a knowledge check or exam became available, they translated the software.

Calculating the percentage change from the initial knowledge check to the final knowledge check for each student revealed more information about how emergent bilinguals use of an intelligent tutoring system improved their progress with the ALEKS software. All but four of the digital informants depicted in both Figure 5.11 and Table 5.4 showed a percentage increase between their initial and final assessment. These findings indicate that emergent bilinguals created a bilingual digital environment which required more time to attain similar grades as their English-dominant counterparts. Emergent bilinguals showed a greater

improvement likely due to their digital practices and use of culturally relevant videos. Analysis of the average time each of the two groups spent on ALEKS indicated that emergent bilinguals spent less than ten additional hours on ALEKS. These two results further indicated that emergent bilinguals were learning more mathematics in approximately the same amount of time. To understand if this affected emergent bilinguals' self-efficacy, two self-efficacy surveys were distributed during both the 2016 spring and fall semesters, to measure these students' confidence with mathematics and technology.

Table 5.4.

Percent difference from initial to final assessment.

	Emergent bilinguals		English Dominant
A	51.61%		86.30%
A	84.72%		70.45%
A	58.75%		75.82%
A	92.59%		36.71%
A	41.46%		11.54%
B	81.48%		91.23%
B	59.15%		48.33%
B	23.44%		37.70%
B	85.96%		72.46%
C-B	85.71%		8.96%
C	83.58%		57.89%
C	88.89%		87.69%
Average	69.78%		57.09%

Research Question 2: Do digital meaning making practices such as email, course forums, texting, translating software, YouTube videos, and blogs impact self-efficacy? The second research question was designed to discover an association between emergent bilinguals' digital practices. Of particular interest were associations between emergent bilinguals' practice of translating ALEKS into Spanish and their self-efficacy towards mathematics and technology. To investigate such potential associations, pre-surveys consisting of the Mathematics Self-

Efficacy Scale (MSES) and the Mathematics and Technology Attitudes Scale (MTAS) were completed by participants of the spring and fall 2016 semester during phase one of this study. Post-surveys of both instruments were conducted during phase three. Statistical analysis and interpretation of the results were conducted during phase four of this study.

The MSES measured a participant's confidence in performing everyday mathematical operations and their confidence in attaining an A or B in future math and science classes. This survey was scored on a five-point Likert-scale, with; "0-1" meaning the participant had "no confidence" in performing the mathematical operation and "8-9" meaning they had "complete confidence." The MTAS measured a student's confidence in mathematics as well as their confidence in using technology for or with mathematics. The MTAS survey also utilized a 5 point Likert-scale. Each survey will be discussed individually.

Mathematical Self-Efficacy Scale: MSES. A two-way multivariate analysis of variance (two-way MANOVA) was conducted on the MSES pre- and post-surveys ($N = 13$) with the two independent variables being the MSES surveys and whether a student translated the software or not. A representative group of ten English-dominant students with grades and learning trajectories similar to those of the Digital informants was randomly selected in the spring of 2016. The analysis showed that there was no statistically significant interaction nor a correlation between the MSES and whether a student translated the software ($F(18,5) = 0.316, p = 0.968;\ Wilks' \Lambda = 0.468$).

Results from the spring and fall 2016 MSES surveys revealed that the English-dominant student group showed a slightly larger increase in their self-efficacy as compared to emergent bilinguals. Figure 5.13 depicts the MSES pre-survey results for both groups with a dotted red line and their MSES post-survey results with a solid black line. The MSES contained 18

questions which are depicted by the numbers around the radar plot (Figure 5.13). Responses to each question ranged from 0 to 9. These numbers are depicted in Figure 5.13 radially from the center of the graph. Although English-dominant students showed a slightly higher increase in self-efficacy performing everyday mathematical tasks, emergent bilinguals did increase their self-efficacy with four survey items.

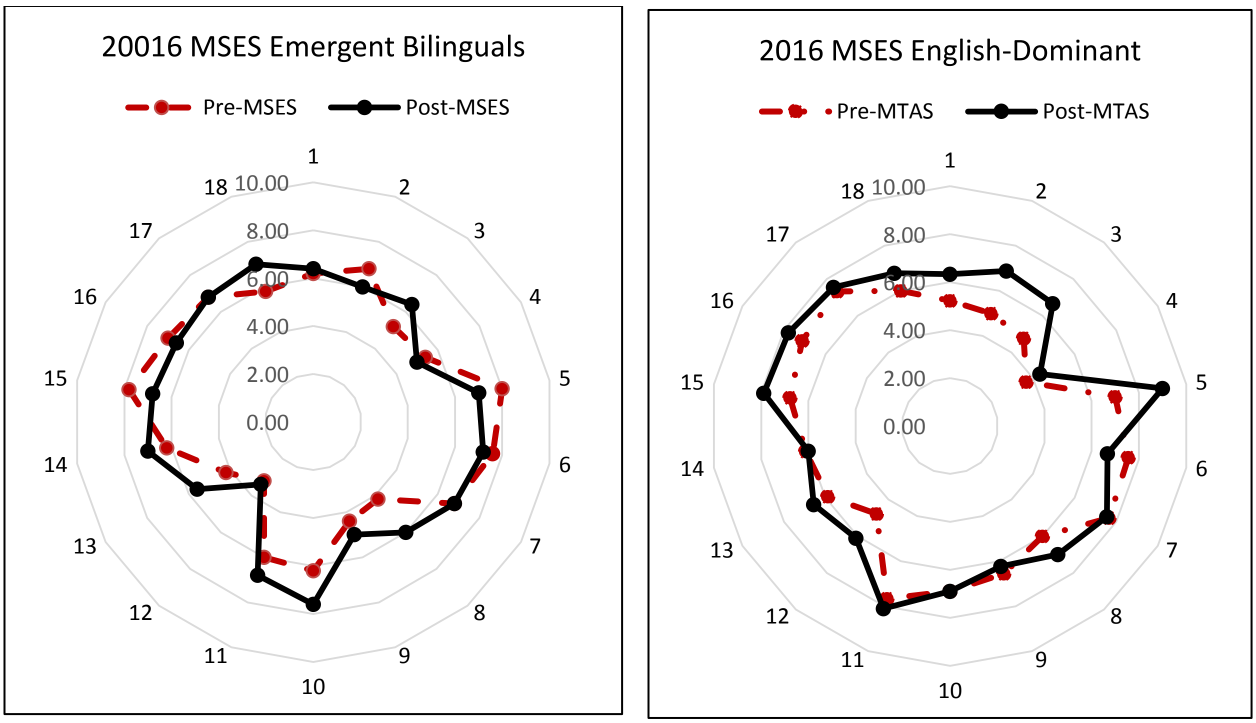


Figure 5.13. Radar chart of pre- and post- MSES results for Digital informants and English-dominant students.

Figure 5.14 depicts the four survey items in which emergent bilinguals increased their self-efficacy (a complete list of MSES survey items can be found in Appendix G). The striped bars in Figure 5.14 indicate the pre-MSES results while the solid black bars indicate the post-MSES results. Emergent bilinguals' digital practices provided them with the tools to feel confident in performing these daily mathematical tasks. Item 13, "understanding a graph

accompanying an article on business profits" was an important item, since researchers have continued to debunk that emergent bilinguals have difficulties in reading and deciphering graphs (Moschkovich, 1996). According to Jablonka, (2003) digital literacies involve developing problem-solving skills which involve understanding graphs and tables in e-textbooks and online journals. Comparing the MSES pre-survey and MSES post-survey between the two groups is depicted in Figure 5.15.

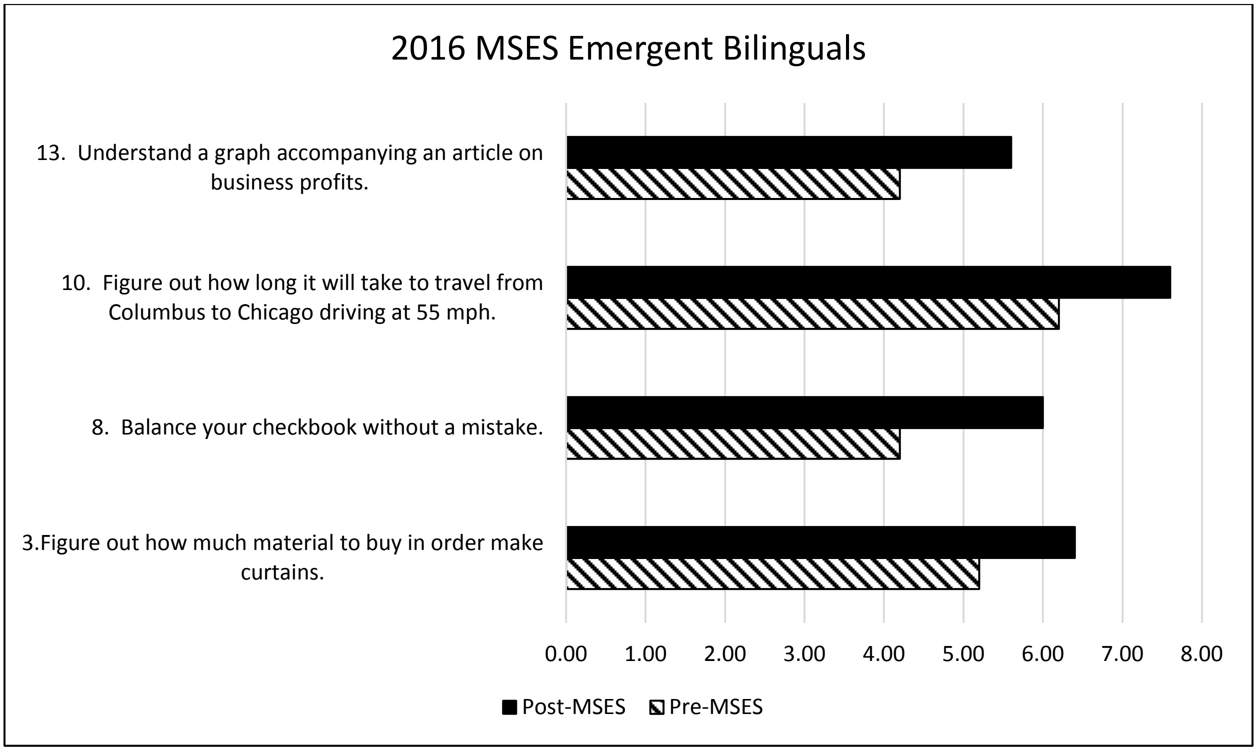


Figure 5.14. Bar graph depicting emergent bilinguals improved self-efficacy in the MSES.

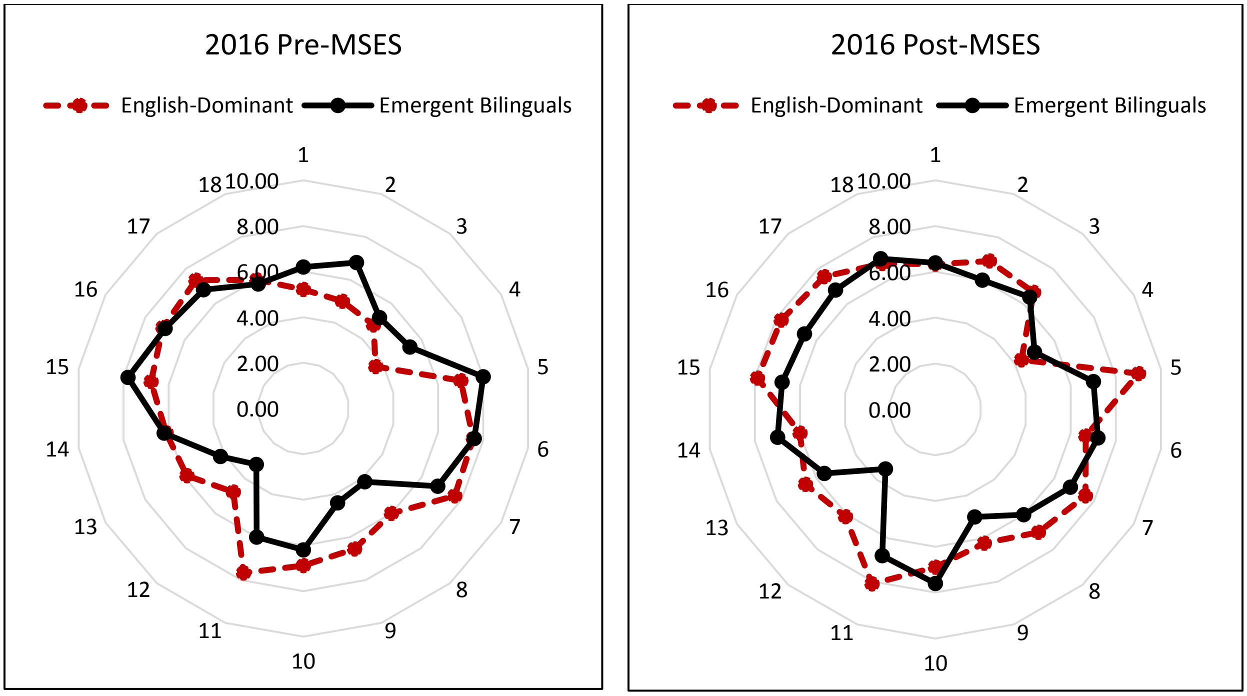


Figure 5.15. Comparison of MSES results between Emergent Bilinguals vs. English Dominant students.

When compared directly with English-dominant students, the MSES results of emergent bilinguals MSES showed that the latter group's self-efficacy was initially equivalent or higher in the pre-survey, but decreased in the post-survey. These finds are depicted in Figure 5.16. However, there was one item on the MSES in which emergent bilinguals had a significant increase. Pre-survey results for the emergent bilinguals group showed that their self-efficacy for Item 10, "Figure out how long it will take to travel from Columbus to Chicago driving at 55 mph," was almost one point lower than their English-dominant counterparts. On the MSES post-survey, English-dominant students' self-efficacy remained stagnant while emergent bilinguals' self-efficacy increased by 1.4 points. These results are an indication that further study into emergent bilinguals' engagement in online mathematics courses and how their digital practices affect their self-efficacy is required. The MTAS surveys were analyzed.

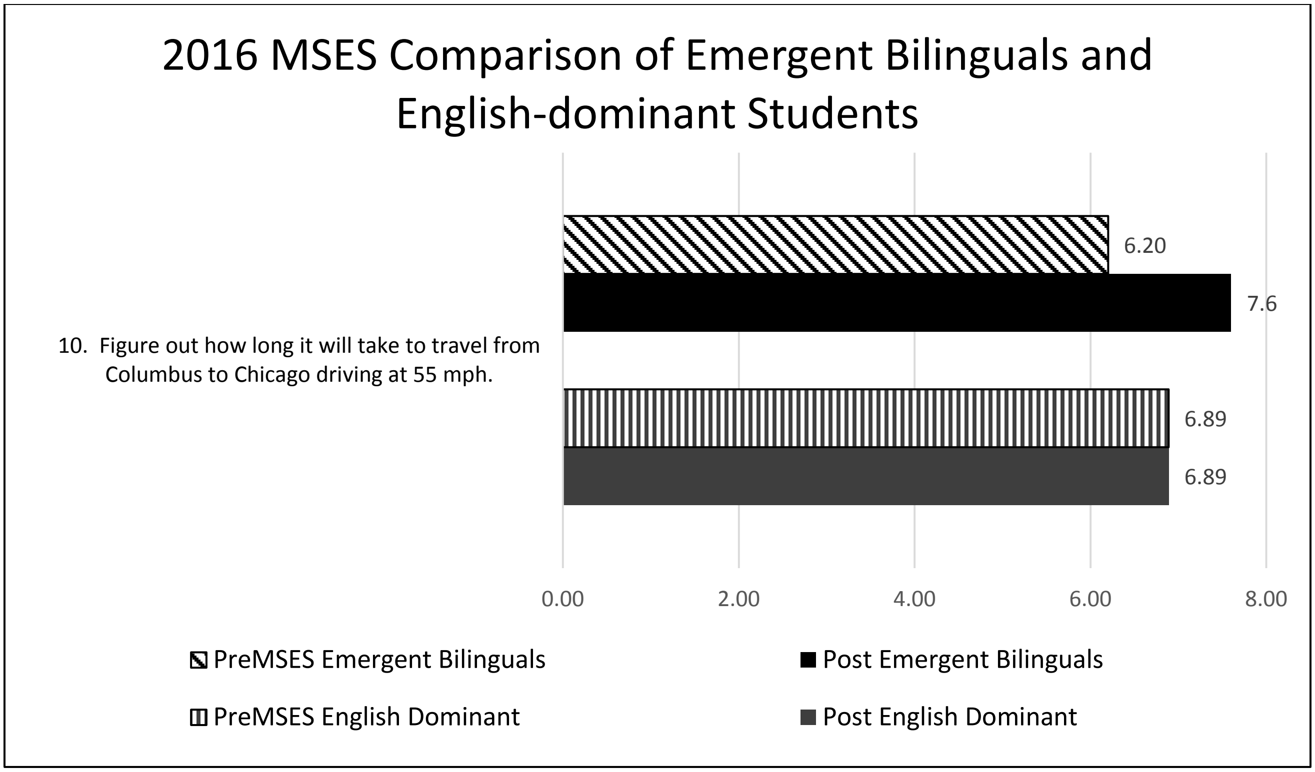


Figure 5.16. Bar graph depicting emergent bilinguals improved self-efficacy in item 10 compared with English-dominant self-efficacy.

Mathematics and Technology Attitude Scale: MTAS. A two-way multivariate analysis of variance (two-way MANOVA) was also conducted on the MTAS pre- and post-surveys ($N = 13$) collected in the spring 2016 semester, 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 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. These items are described in greater detail below.

Figure 5.17 is a display of a radar plot in which the pre-survey and post-survey scores for the MTAS are shown within each group (a complete list of MSES survey items can be found in

Appendix H). The MTAS consisted of 20 items related to mathematics and technology. The item numbers are shown on the outer circle of the radar plot (Figure 5.17). This survey was scored on a five-point Likert-scale, with “1” meaning the participant had “no confidence” with mathematics or technology and “5” meaning they had “complete confidence.” These numbers are depicted in Figure 5.17 radially from the center of the graph. The radar plots depicted in Figure 5.17 show little if any increase in self-efficacy for both groups. Figure 5.18 shows the MTAS pre- and post-survey results between groups. Figure 5.18 shows that emergent bilinguals’ self-efficacy was greater than their English-dominant counterparts for items one through four. However, there are a number of items that emergent bilinguals not only increased their self-efficacy but surpassed English-dominant student’s self-efficacy.

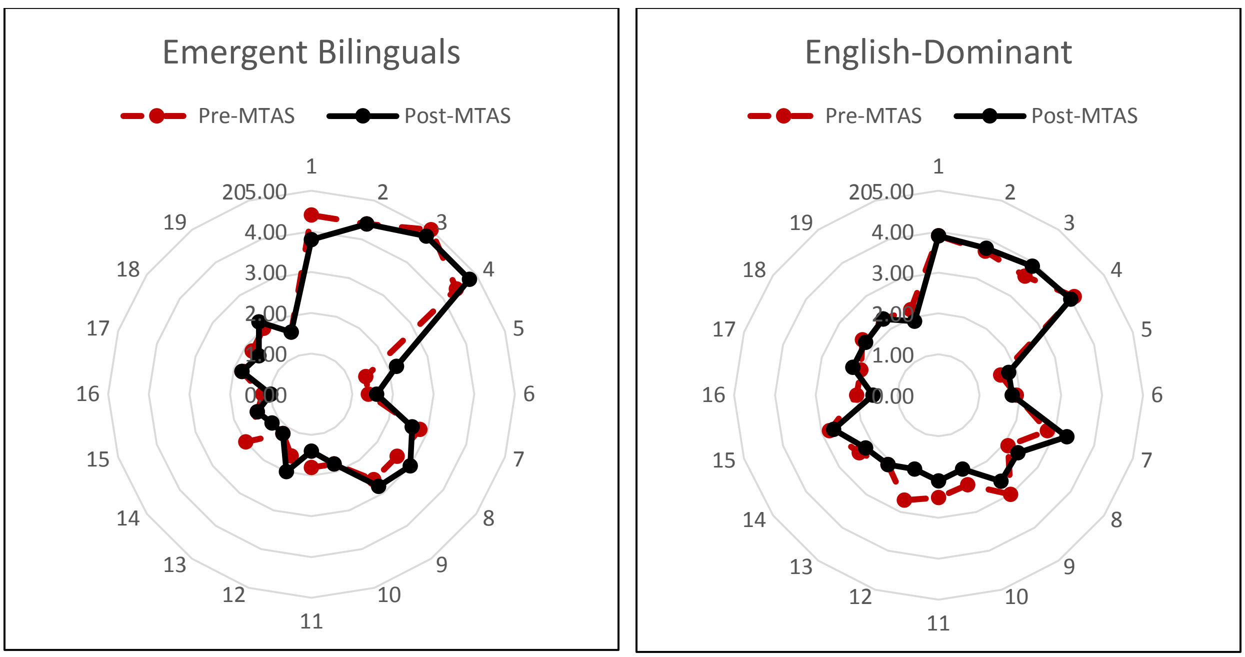


Figure 5.17. Radar chart of MTAS pre- and post-survey results for Digital informants and English-dominant students.

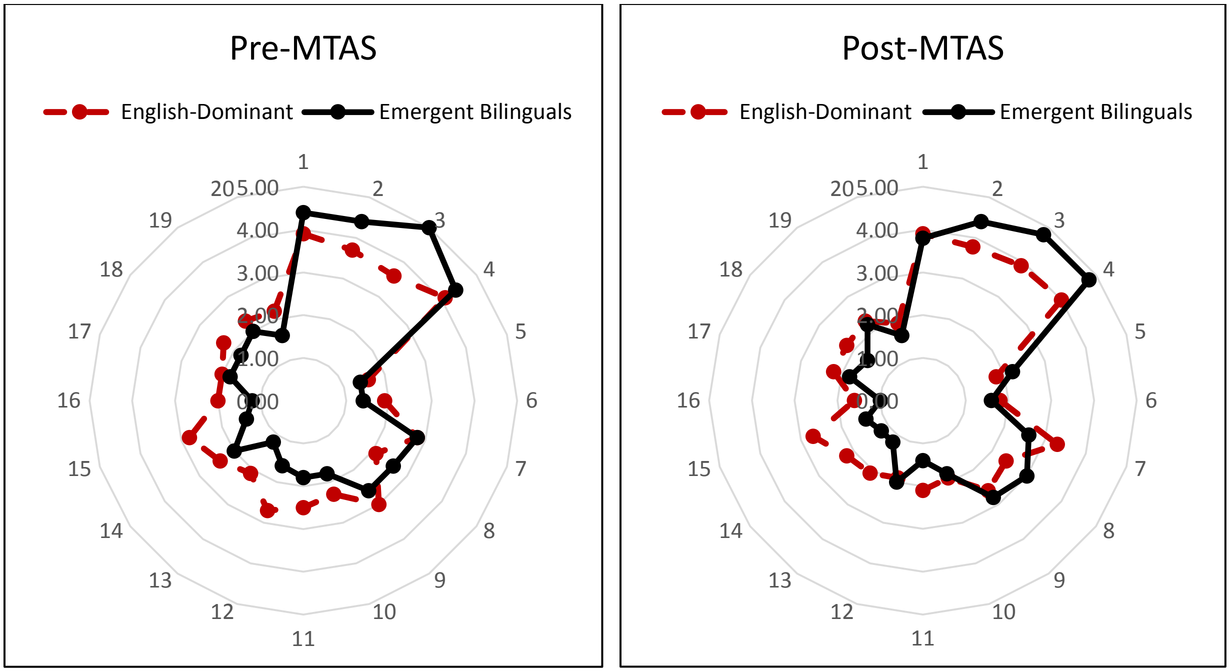


Figure 5.18. Comparison between English Dominant (in Red) and Emergent Bilinguals (in black) MTAS pre- and post-surveys.

Emergent bilinguals in this study were confident in their mathematical skills and digital literacies to find solutions to the practice problems that they completed while engaged in this course. Elizabeth, a Spanish-dominant participant, stated: "I feel confident [with ALEKS] and look forward to what is next." Utilizing these digital meaning making strategies, emergent bilinguals improved their self-efficacy as shown by the six items in Figure 5.19 and Figure 5.20.

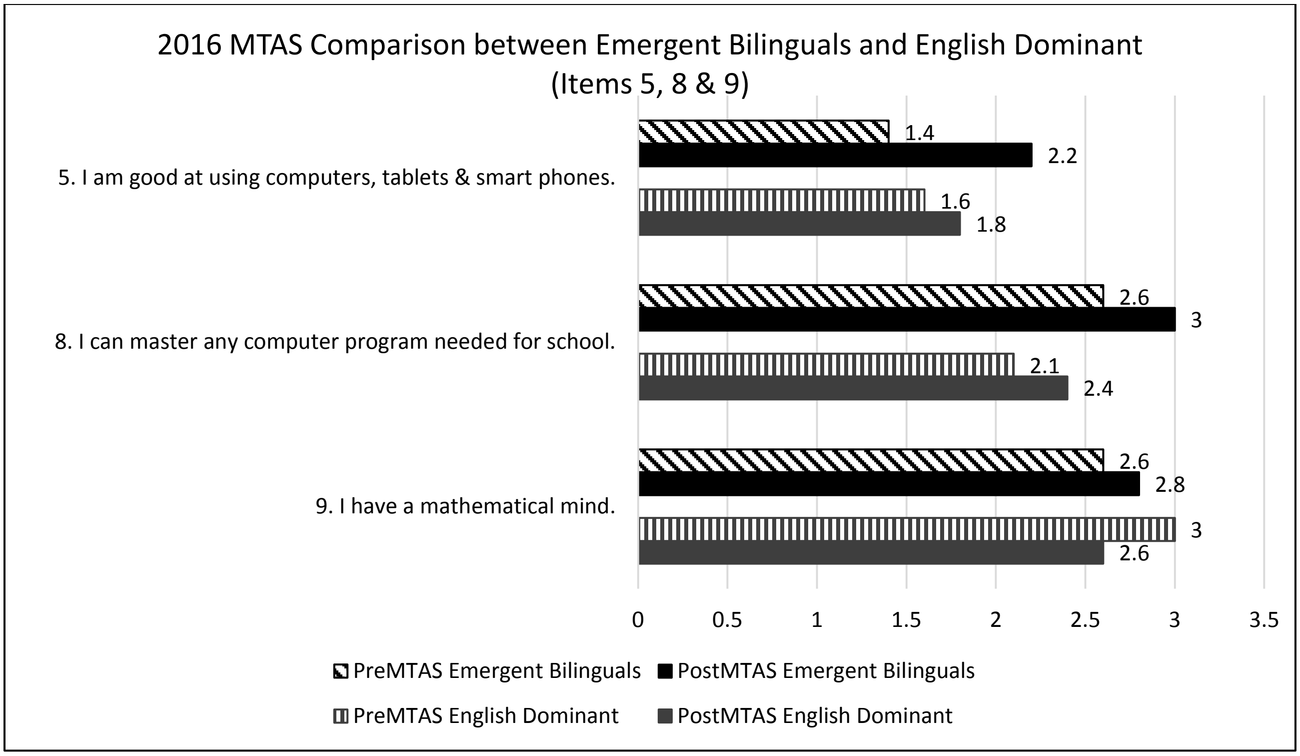


Figure 5.19. Bar graph showing improved self-efficacy for three MTAS items.

Emergent bilinguals not only increased their self-efficacy over their English-dominant peers in using computers, tablets, and smartphones, but they had a greater increase in self-efficacy. Translating the ALEKS software and utilizing online translators allowed emergent bilinguals to make meaning of English vocabulary and increased their attitude towards class required computer programs. Through their digital practices, emergent bilinguals developed agency in their mathematical education and increased their mastery of the topics in ALEKS. For emergent bilinguals, this translated to mastering any computer program required for school (Item 8 in Figure 5.19). 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. However, English-dominant students' self-efficacy in their belief of having a mathematical mind decreased.

Not only did English-dominant students' self-efficacy in their belief that they have a mathematical mind decrease, their confidence in mathematics also decreased (see Figure 5.20).

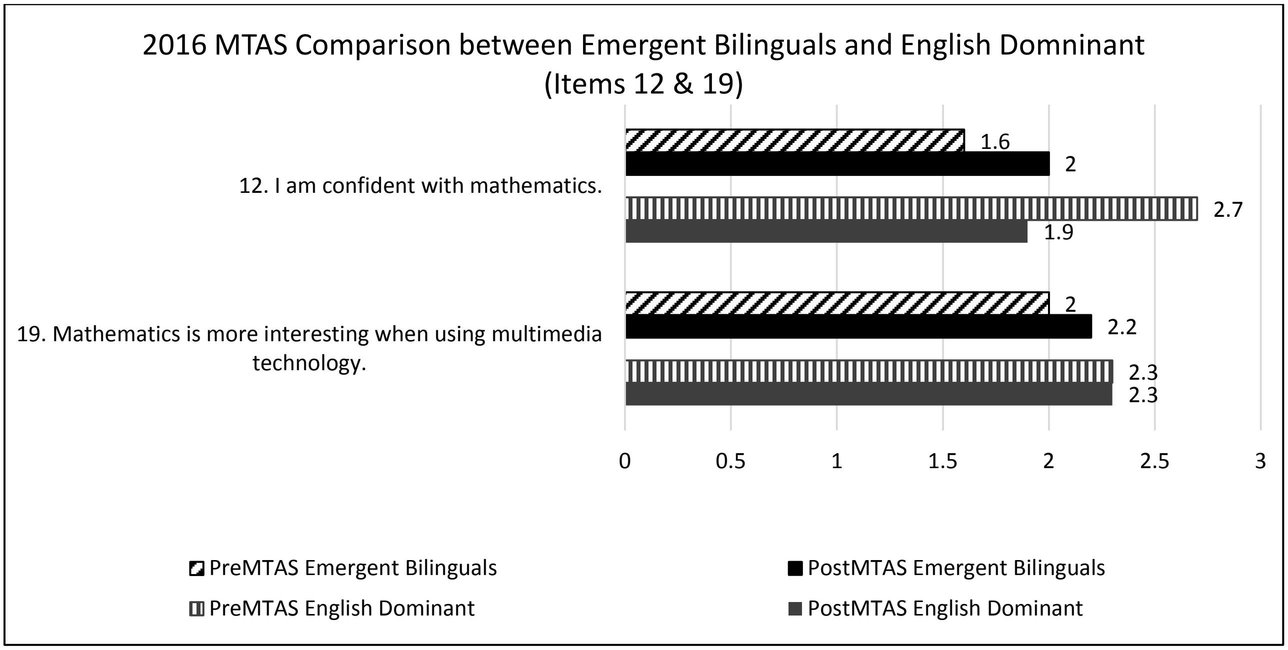


Figure 5.20. Bar graph showing improved self-efficacy for two MTAS items.

Emergent bilinguals were creating a bilingual digital learning environment that encouraged them to make mathematical meaning in both English and Spanish. Their confidence in mathematics increased as seen in Figure 5.20. Although emergent bilinguals required more time on ALEKS and online for meaning making, ultimately they became meaning producers which increased their self-efficacy in mathematics through the use of their digital practices. This was also shown in Figure 5.20, while their English-dominant peers showed no improvement in their self-efficacy in their belief that multimedia technology makes mathematics more interesting.

Summary of Chapter 5

The research in this study showed the complex sociocultural tensions emergent bilinguals encounter and how they influence their digital activities in a fully online pre-calculus course.

Through constant comparison and content analysis of the qualitative data, this study found that emergent bilinguals engage in several digital activities that interact with an ever growing educational community and an array of, mediated tools; moreover, these interactions change their roles within each activity. The four themes emerged from the data were:

1. the importance of learning English,
2. translating software to Spanish and using online translators;
3. meaning making; and
4. Students creating a bilingual digital learning environment.

In order to explicate how these themes were discovered and how they influenced emergent bilinguals, three activity systems, as adapted from Engeström et al. (1999), were created. These activity systems were:

1. Translating ALEKS
2. Using online translators
3. Finding culturally relevant videos/tutorials

Emergent bilinguals encountered two tensions that transformed their digital practices for meaning making and mathematical comprehension. The two tensions were:

1. The importance of learning English, and
2. Encountering unfamiliar Spanish dialects or translations.

These tensions created an obstacle and influenced emergent bilinguals to develop a complex network of digital activities. A third generation activity system network was developed to diagram and explicate this network of digital activities. They utilized this network to develop agency in their mathematical comprehension and to reach their ultimate outcome, which was to

make a cognitive connection in mathematics in both English and Spanish. Emergent bilinguals created a bilingual online mathematics course where they could develop mathematical biliteracy.

The quantitative data analysis was conducted on the demographic survey to identify Spanish-dominant emergent bilinguals through a cross tabulation of the survey results. Analysis of participants' learning progress and time spent on ALEKS facilitated the understanding of how emergent bilinguals' digital practices affected their progress on ALEKS. Finally, statistical analysis of two self-efficacy surveys was conducted in the 2016 spring semester, showing that emergent bilinguals' self-efficacy was not impacted with any statistical significance. However, emergent bilinguals' self-efficacy did increase on certain survey items.

The first survey administered was the Mathematics Self-Efficacy Survey (MSES). As measured by the MSES, emergent bilinguals' self-efficacy improved on the following survey items (phrased as confidence to complete tasks):

- Figure out how long it will take to travel from Columbus to Chicago driving at 55 mph.
- Understand a graph accompanying an article on business profits.
- Balance your checkbook without a mistake.
- Figure out how much material to buy in order make curtains.

Emergent bilinguals' self-efficacy was greater than English-dominant peers on one MSES survey item:

- Figure out how long it will take to travel from Columbus to Chicago driving at 55 mph.

The second survey administered and completed by participants was the Mathematics and Technology Attitudes Scale (MTAS). Emergent bilinguals' self-efficacy not only increased on the following MTAS survey items but in two cases, emphasized in bold, their increase was greater than the increase of their English-dominant peers.

- **I am good at using computers, tablets and/or smartphones.**
- **I can master any computer program needed for school.**
- I have a mathematical mind.
- I am confident with mathematics.
- Mathematics is more interesting when using multimedia technology.

Emergent bilinguals' self-efficacy was influenced by their digital practices and the agency they developed when they were encouraged to create a bilingual digital learning environment.

Chapter 6

Discussion, Implications, and Conclusions

The purpose of this study was to explore how emergent bilinguals engaged with an online mathematics course at a Hispanic serving institution located on the U.S.-Mexico border. This study sought to explore the meaning making of mathematical lexicon and English vocabulary through emergent bilinguals' digital practices. This study further explored how emergent bilinguals' digital practices affected their learning progress on an intelligent tutoring system, ALEKS. This examination also included whether emergent bilinguals' self-efficacy was effected by their digital practices, in particular, their use of the translation capabilities on ALEKS.

In this chapter, I build on chapter five's presentation of key findings to explicate the meaning of those findings through a discussion of the themes that emerged from the data: the importance of learning English; translating software to Spanish and using online translators; meaning making; and students creating a bilingual digital learning environment. The data collected in this study answered the primary research questions and enriched understanding about emergent bilinguals' engagement with an online mathematics course and the use of their digital practices to improve their mathematical self-efficacy.

Summary of Quantitative Results and Qualitative Key Findings

In this section, a discussion of the summarized results from the four phases of this study is presented. In phase one and two of this study, the quantitative results were based on a cross tabulation of the demographic survey to find the association between responses to different questions. This allowed for the identification and funneling of participants into focus groups of Spanish-dominant emergent bilinguals. From the qualitative findings, three common themes emerged from the inductive analysis of the qualitative data involving course forum questions and

email interviews with 35 Spanish-dominant 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.

The importance of learning English was deeply seeded in participants' sociocultural identity and identified as a tension by third generation Activity Theory (Cole & Engeström, 1993; Engeström et al., 1999). Hispanics believe that learning English is essential for economic and educational success, so much so that they consciously and subconsciously drift towards English dominance (Ballinger & Lyster, 2011; Pomerantz, 2008; Potowski, 2004; Taylor et al., 2012). Results from the qualitative data through an Activity Theory lens, indicate that emergent bilinguals applied the tools at hand, translating the software and using online translators, in their natural (unmediated) function and their cultural (mediated) functions to obtain the object, meaning making (Cole & Engeström, 1993).

A second tension revealed from the qualitative data in phases one and two was encountering unfamiliar Spanish dialect translations. In order to make meaning of English vocabulary and mathematical terminology, emergent bilinguals described their experiences and confusion when translating the software and while utilizing an online translator. These two tensions led to a transformation of their activities as predicted by third generation Activity Theory (Cole & Engeström, 1993; Engeström et al., 1999). Consequently, in the first two phases of this research, I answered the first research question and first research sub-question by creating graphical and systematic evidence of emergent bilinguals' engagement in a fully online mathematics course through their digital actions for meaning making:

1. How do undergraduate emergent bilinguals engage with an online math course?

1-A. How do emergent bilinguals make meaning of mathematical terminology using digital practices?

The qualitative results of this study further revealed that emergent bilinguals developed a mathematical register in grouping complex mathematical, linguistic structures for meaning making (Gay, 2000; O'Halloran, 2015; Moschkovich, 2015; Roth et al., 2015). Emergent bilinguals developed the capacity to break away from an inequitable power relation in a monolingual mathematics course to create individual agency for meaning making of mathematical register and terminology (Garcia & Kleifgen, 2010).

In phase three of this study, the qualitative findings, stemming from a continuation of the course forum questions and email-interviews with Digital informants, continued to support the first three themes. Face-to-face interviews with 6 funneled informants revealed that emergent bilinguals' roles in two activity systems based on translating the software and using online translators were transformed by the two tensions mentioned above, from meaning consumers and digital consumers to meaning and digital producers. Emergent bilinguals produced mathematical reasoning through the use of culturally relevant videos to cognitively connect their meaning making digital practices with the mathematics.

The quantitative results in phase three developed through descriptive statistics from student reports generated through ALEKS; Time-on-Topic Report and Learning Progress Report. Results from the quantitative results indicated that a relationship existed between emergent bilinguals' digital practices and their mathematical comprehension on ALEKS.

The Time-on-Topic Report exhibited that several emergent bilinguals required more time on ALEKS to attain similar grades than English-dominant participants. The average time spent on ALEKS by each groups to attain similar grades differed by less than ten hours. Emergent

bilinguals spent an average of 136 on ALEKS, while English-dominant participants spent on average 127 hours on ALEKS. Time spent on ALEKS by both groups was did not differ by a large margin.

Learning Progress Reports showed that emergent bilinguals' percent increase from their initial assessment and their final assessment was greater than several of their English-dominant counterparts and in a few cases significantly larger. The findings in this phase involving the analysis and interpretation of quantitative data revealed that contrary to racial stereotypes, emergent bilinguals made greater gains on ALEKS than their English-dominant counterparts. The results of the quantitative data in phase three answered the second sub-question:

> 1-B. How does language meaning making with an intelligent tutoring system improve emergent bilinguals' progress with an intelligent tutoring system?

One of the rationales for mixing methods is to connect the quantitative and qualitative methods at one or more point(s) in the study (Creswell & Clark, 2007; Teddlie & Tashakkori, 2012). Therefore, in the research presented here, the mixing of methods occurred in the selection of participants for the qualitative focus groups and in the integration of quantitative results and qualitative findings to develop conclusions and interpretations (Teddlie & Tashakkori, 2012). Regarding mathematical comprehension and mastery, the quantitative results and qualitative findings indicated that emergent bilinguals' meaning making of mathematical vocabulary, syntax and English register combined with utilizing culturally relevant videos allowed them to make cognitive connections with mathematics in both languages. Emergent bilinguals' mastery of the pre-calculus topics is evident by their grades and percent increase they showed from initial to final assessments. Emergent bilinguals were developing mathematical biliteracy, making cognitive connections in both languages.

Self-efficacy. Bandura's (1977) self-efficacy theory served as a framework to explain the results of two surveys conducted in the spring and fall 2016 semesters: the Mathematics Self-Efficacy Survey (MSES) and the Mathematics and Technology Attitudes Scale (MTAS). Bandura postulated the notions of self-efficacy in 1977: "An efficacy expectation is the conviction that one can successfully execute the behavior required to produce the (desired) outcomes" (p.193). In phase one the MSES and MTAS results were recorded and in phase three post-survey results were collected, categorized and analyzed.

A two-way multivariate analysis of variance (two-way MANOVA) was conducted in the spring 2016 semester on both the MTAS and MSES ($N = 13$) with the two independent variables being participants self-efficacy and whether the software was translated by a participant. The analysis showed that there was no statistically significant interaction between self-efficacy with mathematics and technology and whether a student translated the software. Consequently, results of this data were through descriptive statistics comparing self-efficacy for emergent bilinguals with 10 English-dominant participants.

Analysis and integration of both qualitative and quantitative data were conducted in phase four. The MSES results showed that emergent bilinguals' increased their self-efficacy for understanding a graph accompanying an article on business profits. This is significant for emergent bilinguals' mathematical literacy. The ability to decode information given in the form of graphical representations is expected of students to be considered mathematically literate (Niss & Jablonka, 2014; National Council of Teachers of Mathematics, 2013; Siebert, & Draper, 2012).

Comparisons between emergent bilinguals and English-dominant participants with the MSES pre- and post-survey were analyzed in phase four. Analysis of the results indicated that

emergent bilinguals increased their self-efficacy for the survey item, “Figure out how long it will take to travel from Columbus to Chicago driving at 55 mph”, whereas their English-dominant counterparts’ self-efficacy with this item remained unchanged. I inferred that emergent bilinguals develop a higher self-efficacy in computational mathematics due to increasing their mathematical knowledge on ALEKS. This increase in computational mathematics and improved self-efficacy is a direct result of emergent bilinguals’ digital practices.

MTAS results comparing emergent bilinguals to English-dominant participants showed that emergent bilinguals increased their self-efficacy on five survey items. These five items were:

1. I am good at using computers, tablets, and smartphones.
2. I can master any computer program needed for school.
3. I have a mathematical minds.
4. I am confident with mathematics.
5. Mathematics is more interesting when using multimedia technology.

Although both groups improved their self-efficacy with items 1, 2, and 5, the results indicated that emergent bilinguals had a greater increase in their self-efficacy. Integrating two methods in a mixed methods design enhances the quality of a mixed methods design (Teddlie & Tashakkori, 2012). Consequently, emergent bilinguals’ digital practices for meaning making and their development of cognitive connections with mathematics in two languages increased their self-efficacy.

Of greater significance were the items that involved emergent bilinguals confidence with mathematic and their mathematical mindset. Emergent bilinguals increase their self-efficacy with these two items due to their mastery of mathematical concepts utilizing biliterate digital strategies. Their English-dominant participants did not increase their self-efficacy, in fact, these

results showed that their self-efficacy decreased. The results of the quantitative results and the qualitative findings in phase four answered the second research question:

2. Do digital meaning making practices such as email, course forums, texting, translating software, online videos, and blogs impact self-efficacy?

Summary. 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 qualitative findings and quantitative results also revealed that emergent bilinguals made cognitive connections with the 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 quantitative results, based on two self-efficacy instruments, 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.

Implications

This research adds to the literature on emergent bilinguals' self-efficacy in online mathematics courses. This research further indicates that digital practices in online mathematics courses are complex sociocultural endeavors created and mediated by emergent bilinguals. Carpenter (2009) determined that courses which feature technology will be most effective if the utilization of the software has clear objectives and goals. Translating software into an emergent bilinguals' native language allows for the student agency in creating an equitable learning

environment. Utilizing software translation capabilities and online translators give 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.

Albert and Mori (2001) stated, “learning is an adaptive process, the interactive e-learning system has to support this process by being adaptive itself” (p. 6). Emergent bilinguals adapt their digital activities to create a bilingual digital learning environment. When software supports emergent bilinguals’ language and culture then it can be mediated to create equitable digital environments. Many online mathematics courses continue to present course material in a linear format, utilizing online interactive educational systems that mirror the curriculum of face-to-face classrooms. The results of this study indicate that learning in a fully online mathematics course is a complex activity endeavor for emergent bilinguals. The findings from this research indicate a need for further research in the following areas:

1. Updating self-efficacy instrument for emergent bilinguals with the use of technology in mathematics courses.
2. Updating self-efficacy instruments for emergent bilinguals and online mathematics courses.
3. Emergent bilinguals’ digital literacies and how this may affect their self-efficacy in online mathematics courses.
4. The impact of monolingual online mathematics course on emergent bilinguals’ agency.
5. How transnational emergent bilinguals engage in an online mathematics course.
6. Community tensions involving emergent bilinguals and transfronterizo

One major challenge is to train and prepare practitioners of online mathematics courses. 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 resource in both English and Spanish to contend with mathematical syntax, content misconceptions, and language misunderstandings. Analysis on this topics is presented in work by Lesser, Wagler, and Salazar, (2016).

Assumptions

As a scholar, I assumed that the findings of this study would be based on my experience as a practitioner. I assumed that once translated emergent bilingual participants would not return to the English version of the software as a meaning making strategy. I further assumed that all emergent bilinguals regardless of their language proficiency level would use this strategy. Since I am a lifelong resident of this region and as an emergent bilingual as well, I assumed the participants' responses to course forum questions, email questions and interviews were provided openly and with all honesty. I further assumed that I asked the correct questions for each form of data collection.

Study Limitations

The limitations of this study were:

1. This dissertation study is of students who enrolled in a fully online pre-calculus course so a comparison to other online pre-calculus courses of different design utilizing various online interactive educational systems may not be valid.

2. The utility of the findings is limited to a pre-calculus course at this university on the U.S.-Mexico border.
3. The uniqueness of this study within ALEKS makes it difficult to replicate in other online pre-calculus courses which use different software programs.
4. The qualitative data was self-reported. I as the instructor/researchers relationships with Spanish-dominant emergent bilinguals were developed and cultivated in the hopes that participants would provide truthful and meaningful information.
5. Sampling for the quantitative data was through a convenience sampling and a sequential mixed methods sampling technique. Since the self-efficacy instruments utilized in this study were offered to participants in two of the four semesters, the sample size for both surveys was small hence the multivariate analysis of the data was not statistically significant.

Conclusions

The purpose of this mixed methods research was to analyze how emergent bilinguals engaged with a fully online pre-calculus course and how their self-efficacy was effected by their digital practices. To understand this engagement more deeply the purpose of this study was: to analyze how emergent bilinguals utilized their digital practices for meaning making and making cognitive connections with the mathematics; and to analyze how their meaning making digital practices affected their progress on ALEKS. The overall results provide evidence of how emergent bilinguals' digital practices allowed them to make meaning of mathematical syntax and English register to comprehend mathematical content.

Furthermore, as evidenced by the research findings presented here, emergent bilinguals increased their self-efficacy with both mathematics and technology. Emergent bilinguals' digital

practices of making meaning and utilizing culturally relevant videos to comprehend the mathematics allowed them to develop mathematical biliteracy. Emergent bilinguals were learning and mastering mathematical concepts in both English and Spanish. They were integrating their prior knowledge of the subject, which the language of instruction was Spanish, with new and future topics that were presented in English.

Understanding the role of language and culture is important for practitioners, researchers, and developers of online mathematics courses. This study revealed a set of tools; demographic surveys, a math self-efficacy survey and a math and technology survey, course forum posts, daily logs, screenshots, and email-interviews, (See appendices F, G, H, J, K, M, and N for description of each instrument) that could be used in future studies to answer innovative research questions. Although this study answered those questions in relation to emergent bilinguals enrolled in a fully online mathematics course, future research is unmistakably needed to expand the findings presented in this study and answer remaining research questions.

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Appendix A

University of Texas at El Paso IRB Approval for Summer Bridge Program 2013

THE UNIVERSITY OF TEXAS AT EL PASO
Office of the Vice President for Research and Sponsored Projects
Institutional Review Board
El Paso, Texas 79968-0587
phone: 915 747-8841 fax: 915 747-5931

FWA No: 00001224

DATE:	August 6, 2013
TO:	Julian Viera, M.S.
FROM:	University of Texas at El Paso IRB
STUDY TITLE:	[460154-1] The effectiveness of a cognitive learning computer system in improving basic math skills for entering college students: a mixed methods pilot study
IRB REFERENCE #:	460154-1
SUBMISSION TYPE:	New Project
ACTION:	APPROVED
APPROVAL DATE:	August 6, 2013
EXPIRATION DATE:	August 5, 2014
REVIEW TYPE:	Expedited Review

Thank you for your submission of New Project materials for this research study. University of Texas at El Paso IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This study has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

Please report all NON-COMPLIANCE issues or COMPLAINTS regarding this study to this office.

Please note that all research records must be retained for a minimum of three years after termination of the project.

Based on the risks, this project requires Continuing Review by this office on an annual basis. Please use the appropriate renewal forms for this procedure.

If you have any questions, please contact Athena Fester at (915) 747-8841 or afester@utep.edu. Please include your study title and reference number in all correspondence with this office.

cc:

Appendix B

University of Texas at El Paso IRB Approval for Fall 2014

THE UNIVERSITY OF TEXAS AT EL PASO
Office of the Vice President for Research and Sponsored Projects
Institutional Review Board
El Paso, Texas 79968-0587
phone: 915 747-8841 fax: 915 747-5931

FWA No: 00001224

DATE:	June 6, 2014
TO:	julian viera, M.S.
FROM:	University of Texas at El Paso IRB
STUDY TITLE:	[598204-1] English Language Learners attitudes toward online mathematics courses and the use of intelligent tutoring systems.
IRB REFERENCE #:	598204-1
SUBMISSION TYPE:	New Project
ACTION:	APPROVED
APPROVAL DATE:	June 6, 2014
EXPIRATION DATE:	June 5, 2015
REVIEW TYPE:	Expedited Review

Thank you for your submission of New Project materials for this research study. University of Texas at El Paso IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This study has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

Please report all NON-COMPLIANCE issues or COMPLAINTS regarding this study to this office.

Please note that all research records must be retained for a minimum of three years after termination of the project.

Based on the risks, this project requires Continuing Review by this office on an annual basis. Please use the appropriate renewal forms for this procedure.

If you have any questions, please contact Christina Ramirez at (915) 747-7693 or cramirez22@utep.edu. Please include your study title and reference number in all correspondence with this office.

cc:

Appendix C

University of Texas at El Paso IRB Exempt Letter for fall 2015 and 2016

THE UNIVERSITY OF TEXAS AT EL PASO
Office of the Vice President for Research and Sponsored Projects
Institutional Review Board
El Paso, Texas 79968-0587
phone: 915 747-8841 fax: 915 747-5931

FWA No: 00001224

DATE:	August 12, 2015
TO:	Julian Viera, BS. MS.
FROM:	University of Texas at El Paso IRB
STUDY TITLE:	[777643-1] Mulitmodal digital literacies for English Language Learners in an online mathematics course utilizing an intelligent tutoring system
IRB REFERENCE #:	777643-1
SUBMISSION TYPE:	New Project
ACTION:	DETERMINATION OF EXEMPT STATUS
DECISION DATE:	August 12, 2015

Thank you for your submission of New Project materials for this research study. University of Texas at El Paso IRB has determined this project is EXEMPT FROM IRB REVIEW according to federal regulation **[45 CFR 46.101(b)(1)]:**

- Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special educational instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods

Exempt protocols do not need to be renewed. Please note that it is the Principal Investigator's responsibility to resubmit the proposal for review if there are any modifications made to the originally submitted proposal. This review is required in order to determine if "Exemption" status remains.

We will put a copy of this correspondence on file in our office.

If you have any questions, please contact Christina Ramirez at (915) 747-7693 or cramirez22@utep.edu. Please include your study title and reference number in all correspondence with this office.

cc:

Appendix D

Consent form (English and Spanish) with UTEP stamp of approval

Title:
English Language Learners attitudes toward online mathematics courses and the use of intelligent tutoring systems

Principal Investigator: Julian Viera M.S.
UTEP: Department of Teaching Learning and Culture

Introduction:

You are being asked to take part voluntarily in the research project described below. Please take your time making a decision and feel free to discuss it with your friends and family. Before agreeing to take part in this research study, it is important that you read the consent form that describes the study. Please ask the study researcher to explain any words or information that you do not clearly understand.

Why is this study being done?

You have been asked to take part in a research study about the linguistic and cultural practices involved in an online pre-calculus course.

The survey will be offered to all UTEP students who are enrolled in an online pre-calculus course.

You are being asked to participate in the study because you are over the age of 18, and you are currently enrolled in an online pre-calculus course at UTEP.

If you decide to enroll in this study, your involvement will be less than 5 hours total and in most instances fewer than five minutes per week.

What is involved in the Study?

If you agree to take part in this study, you will be asked to complete a survey about your attitudes towards an online pre-calculus course, as well as your language behaviors in this course. You will be asked to answer weekly course forum questions in addition to your mandatory 8 hours spent on the online program. You will be asked to complete a post survey. Your time spent on the online program and your weekly progress will be observed and recorded by the researcher.

What are the risks and discomforts of the study?

A potential risk may be anxiety about having the researchers as the instructor of this course. Student identifying markers, such as names and IDs, will be codes and kept confidential by the researcher/instructor.

What will happen if I am injured in this study?

Approved on: 06/06/2014
Expires on: 06/05/2015
Study Number: Viera 598204-1

Physical injury is not expected in this study, however The University of Texas at El Paso and its affiliates do not offer to pay for or cover the cost of medical treatment for research related illness or injury. No funds have been set aside to pay or reimburse you in the event of such injury or illness. You will not give up any of your legal rights by signing this consent form.

Are they any benefits to taking part in this study?

Students may discover how language and culture are utilized to learn mathematics. Students may discover how language can be an asset for online math courses.

What other options are there?

You have the option not to take part in this study. There will be no penalties involved if you choose not to take part in this study.

Who is paying for this study?

There is no funding at this time for this study.

What are my costs?

There are no direct costs.

Will I be paid to participate in this study?

There are no monetary payments for participating in this study.

What if I want to withdraw, or am asked to withdraw from this study?

Taking part in this study is voluntary. You have the right to choose not to take part in this study. If you do not take part in the study, there will be no penalty.

If you choose to take part, you have the right to stop at any time. However, you are encouraged to contact the researcher of the study so that he knows why you are leaving the study. If there are any new findings during the study that may affect whether you want to continue to take part, you will be told about them.

The researcher may decide to stop your participation without your permission, if he or she thinks that being in the study may cause you harm, or if it is found that you do not meet the requirements to participate in the study (i.e. you are under the age of 18, are not a current UTEP student).

Who do I call if I have questions or problems?

If you have questions, you may call Julian Viera at (915) 747-6770.

What about confidentiality?

Every effort will be made to keep your information confidential. Student identifying markers will be coded. Online signed consent forms will not be attached to survey forms; thus, surveys do not contain identifying information. Your personal information may be disclosed if required by law.

All records will be kept in secure electronic files and only the researcher will have access to them.

***Authorization Statement**

I have read each page of this paper about the study (or it was read to me). I know that being in this study is voluntary and I choose to be in this study. I know I can stop being in this study without penalty. I will get a copy of this consent form now and can get information on results of the study later if I wish. By typing your name below, you consent to participate in this study.

Título:
Actitudes English Language Learners en cursos de matemáticas en línea y el uso de sistemas de tutorías inteligentes

Investigador principal: Julian Viera M.S.
UTEP: Departamento de Teaching Learning and Culuture

Introducción:
Se les ha pedido a participar voluntariamente en el proyecto de investigación que se describe a continuación. Por favor, tómese su tiempo tomar una decisión y no dude en hablar con sus amigos y familiares. Antes de aceptar participar en este estudio de investigación, es importante que lea el formulario de consentimiento que describe el estudio. Consulte con el investigador del estudio para explicar cualquier palabra o información que usted no entiende claramente.

¿Por qué se está haciendo este estudio?
Le han pedido participar en un estudio de investigación sobre las prácticas lingüísticas y culturales involucradas en un curso en línea de pre-cálculo.
La encuesta se ofrecerá a todos los estudiantes UTEP que están matriculados en un curso en línea de pre-cálculo.
Se les ha pedido participar en el estudio porque eres mayor de 18 años, y actualmente está inscrito en un curso en línea de pre-cálculo en UTEP.
Si usted decide inscribirse en este estudio, la participación de menos de 5 horas en total y en la mayoría de los casos será menos de cinco minutos por semana.

¿Qué está involucrado en el estudio?
Si usted acepta participar en este estudio, se le pedirá completar una encuesta sobre sus actitudes hacia un curso en línea de pre-cálculo, así como sus comportamientos de lengua en este curso. Se le pedirá a responder preguntas de foro curso semanal además sus obligatorios 8 horas en el programa en línea. Se le pedirá completar una encuesta post. El tiempo invertido en el programa en línea y su progreso semanal será observado y registrado por el investigador.

¿Cuáles son los riesgos y molestias del estudio?
Un riesgo potencial puede ser ansiedad por tener los investigadores como el instructor de este curso. Identificación de marcadores, tales como nombres y IDs, estudiante será codificada y confidencial por el investigador/instructor.

¿Qué pasará si me lesiono en este estudio?
Lesión física no se espera en este estudio, sin embargo la Universidad de Texas en El Paso y sus afiliadas no ofrecen pagar o cubrir el costo del tratamiento médico para la investigación relacionada con la enfermedad o lesión. No han reservado fondos para pagar o reembolsar en caso de tal lesión o enfermedad. No darás a cualquiera de sus derechos legales al firmar este formulario de consentimiento.

¿Qué son los beneficios de tomar parte en este estudio?
Los estudiantes pueden descubrir cómo la lengua y la cultura son utilizados para aprender matemáticas. Los estudiantes pueden descubrir cómo el lenguaje puede ser una ventaja para los cursos de matemáticas en línea.

¿Qué otras opciones existen?
Tienes la opción de no participar en este estudio. No habrá ninguna sanción si decide no participar en este estudio.

¿Quién paga para este estudio?

No hay ninguna financiación en este momento para este estudio.

¿Cuáles son mis costos?

No hay costos directos.

¿Se me pagará a participar en este estudio?

No hay ningún pago monetario por participar en este estudio.

¿Qué pasa si quiero retirar, o se me pide que retire de este estudio?

Tomar parte en este estudio es voluntaria. Usted tiene el derecho de optar por no participar en este estudio. Si usted no toma parte en el estudio, no habrá ninguna pena.

Si usted decide participar, usted tiene el derecho de detener en cualquier momento. Sin embargo, le animamos a contactar con el investigador del estudio para que él sabe por qué vas del estudio.

Si hay cualquier nuevos hallazgos durante el estudio que pueda afectar si desea continuar a participar, le contarán acerca de ellos.

El investigador puede decidir dejar su participación sin su permiso, si él o ella cree que estar en el estudio puede causarle daño, o si es que no cumples los requisitos para participar en el estudio (por ejemplo, está bajo la edad de 18 años, no es un estudiante de UTEP actual).

¿A quién llamo si tengo preguntas o problemas?

Si usted tiene preguntas, puede llamar a Julian Viera al (915) 747-6770.

¿Qué pasa con la confidencialidad?

Se realizará todos los esfuerzos posibles para mantener su información confidencial. Estudiante identificar marcadores a codificarse. Formularios de consentimiento firmado en línea no se unirá para examinar las formas; por lo tanto, las encuestas no contienen información de identificación. Puede divulgar su información personal si es requerido por ley.

Todos los registros serán conservados en los archivos electrónicos seguros y sólo el investigador tendrá acceso a ellos.

*** Autorización Declaración**

He leído cada página de este documento sobre el estudio (o fue leído a mí). Sé que en este estudio es voluntaria y decido participar en este estudio. Sé que puedo dejar de estar en este estudio sin penalización. Me recibirá una copia de este formulario de consentimiento a petición por correo electrónico y puede obtener información sobre los resultados del estudio más tarde si quisiera. Escribiendo tu nombre a continuación, usted da su consentimiento para participar en este estudio y seguirá una encuesta demográfica.

Appendix E:

Math 1508 online Pre-calculus syllabus spring 2016

THE UNIVERSITY OF TEXAS AT EL PASO
COLLEGE OF SCIENCE
DEPARTMENT OF MATH

Course #:	Math 1508:
Course Title:	Pre-Calculus: Online course code: 9QMCJ-NDTDW
Credit Hours:	5
Term:	Fall 2016
Course Meetings & Location:	NONE
Prerequisite Courses:	M0311 or placement by Accuplacer
Instructor:	Julian Viera Jr.
Office Location:	Bell Hall 119
Contact Info:	747-6770

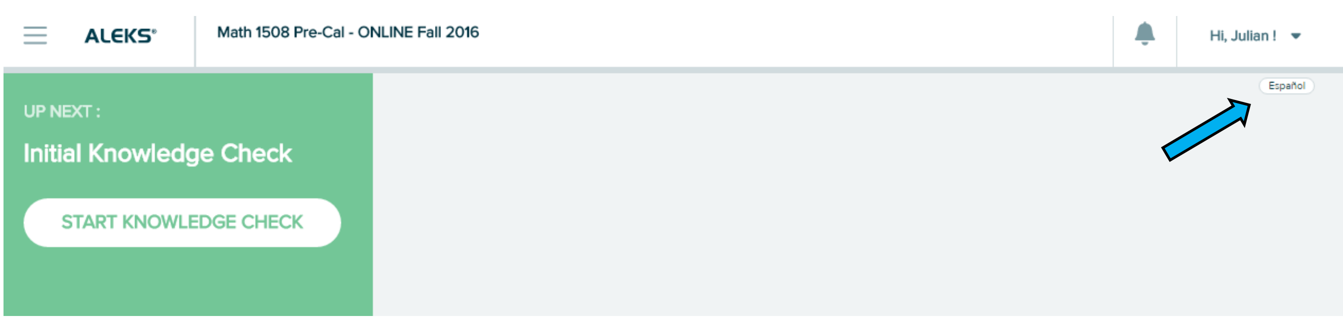
E-mail address: jviera1@utep.edu
Emergency Contact: 747-6770

Office Hours: MTWR 9:30 – 11:20 AM or by appointment.

Contact Customer Support for any trouble with ALEKS - Higher Education
Hours (MST):
Sunday: 2:00 PM to 11:00 PM
Monday – Thursday: 5:00 AM to 11:00 PM
Friday: 5:00 AM to 7:00 PM
Phone: (714) 619-7090
Fax: (714) 245-7190
Email: contact us at http://support.aleks.com

Required Textbook(s), Materials: Aleks 360 with eText: http://www.aleks.com

Nota: Este programa se puede cambiar a español si es necesario haciendo clic en el marcado Español de menú desplegable.



Description:

“When a student first logs on to ALEKS, a brief tutorial shows him how to use these ALEKS answer input tools. The student then begins the ALEKS Assessment. In a short period of time (about 45 minutes for most courses), ALEKS assesses the student's current course knowledge by asking him a small number of questions (usually 20-30).”

“To ensure that topics learned are retained in long term memory, ALEKS periodically reassesses the student, using the results to adjust the student's knowledge of the course. Because students are forced to show mastery through mixed question assessments that cannot be predicted, mastery of the ALEKS course means true mastery of the course.”

Course Objectives (Learning Outcomes):

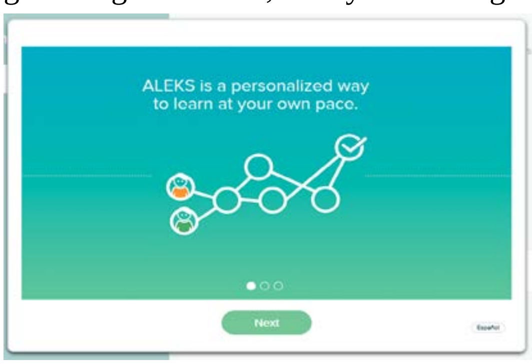
Students are expected to have a clear understanding of the ideas of Precalculus as a solid foundation for subsequent courses in mathematics and other disciplines as well as for direct application to real life situations.

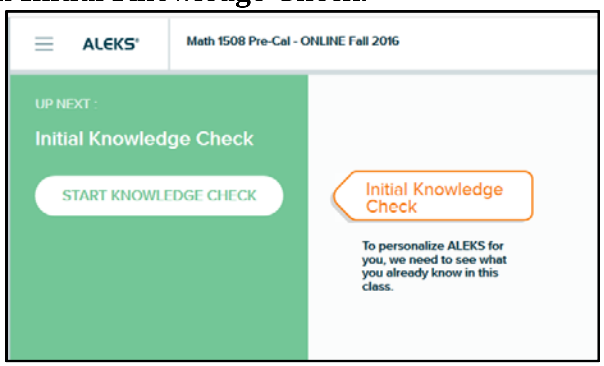
The content of the entire course covers topics from basic mathematics and develop them using practical and theoretical tools, building applications and making a strong support for Calculus classes.

A student passing MATH1508 Precalculus course will be able to work with the concepts of functions (functions in general, exponential and logarithmic functions, polynomial and rational functions, trigonometric functions, etc), to solve a system of linear and non-linear equations and inequalities, to make basic operations with matrices, to apply mathematical induction method, to work with trigonometric functions and their properties, and to apply in problems related to other branches of Science: Calculus, Algebra, Physics, Chemistry, Biology, Pharmacy, Engineering, Statistics, etc.

Course Activities/Assignments:

You will find all work on http://www.aleks.com . When you log onto ALEKS you will go through a tutorial, then you will begin an **Initial Knowledge Check.**





You must complete your Initial Knowledge Check by September 2 at midnight. Failure to complete the initial knowledge check will lead to being dropped from this course. If you are dropped you may lose your financial aid, so please complete your initial assessment.

Once you have completed your initial assessment, click on CONTINUE MY PATH, then beginning working on the practice problems. You do not have assignments or quizzes, just click on CONTINUE MY PATH.

Paper Notebook (not graded): You must keep a notebook of everything you do on ALEKS. Every problem, every definition, all notes must be entered into your "hand written" notebook. You will not turn in this notebook.

Course forum questions will be posted beginning the third week of the semester. There will be 6 to 8 forum questions to reply to. These questions are optional and for extra credit.

Assessment of Course Objectives:

You will have a Midterm over Functions and Graphs, Polynomial and Rational Functions, Exponential Functions and Matrices. The Midterm will appear on ALEKS Sunday, October 9 at 12:01AM and close on Sunday, October 9, at 11:59PM. You may take the Midterm early if you complete the TOPICS listed in the objective. You must contact me if you want to take the midterm early. The Final exam will be available on Wednesday, December 7 at 12:00 noon and close on Thursday, December 8 at 11:59PM.

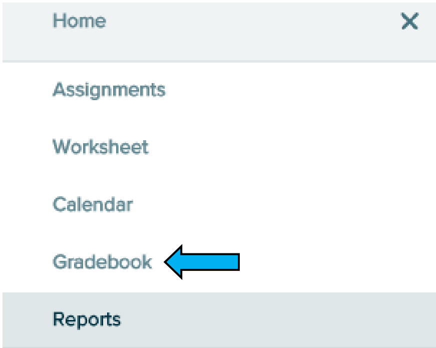
Grading Policy:

There are three objectives. Review Topics, Prep for Midterm and Trigonometry.
Your grade for this course will be calculated as shown below:

Review Topics	05%
Prep for Midterm	15%
Midterm Exam	30%
Trigonometry	15%
Final Exam	35%

You can check your grade at any time by clicking on the Menu bars,

Then click on Gradebook



The Drop Date for this semester is October 28, 2016.

Make-up Policy:

No makeup exams will be allowed except with proper documentation, i.e. doctor's note, hospital's note, or UTEP excused absence document.

Attendance Policy:

Students must work on ALEKs a minimum of 8 hours per week. Failure to work on ALEKs 8 hours per week may result in you being dropped from the course. Students are **recommended to complete a minimum** of 25-30 topics per week in order to complete this course successfully.

Academic Integrity Policy:

Cheating on a Test or Quiz must be dealt with in accordance with University regulations. This means automatic referral to and adjudication by the Dean of Students. During a Test or Quiz, you must present yourself in a manner that reflects an understanding of the traditional standards of academic honesty.

Disability Statement:

If you have a disability and need classroom accommodations, please contact The Center for Accommodations and Support Services (CASS) at 747-5148, or by email to cass@utep.edu, or visit their office located in UTEP Union East, Room 106. For additional information, please visit the CASS website at www.utep.edu/CASS. CASS' Staff are the only individuals who can validate and if need be, authorize accommodations for students with disabilities.

Military Statement:

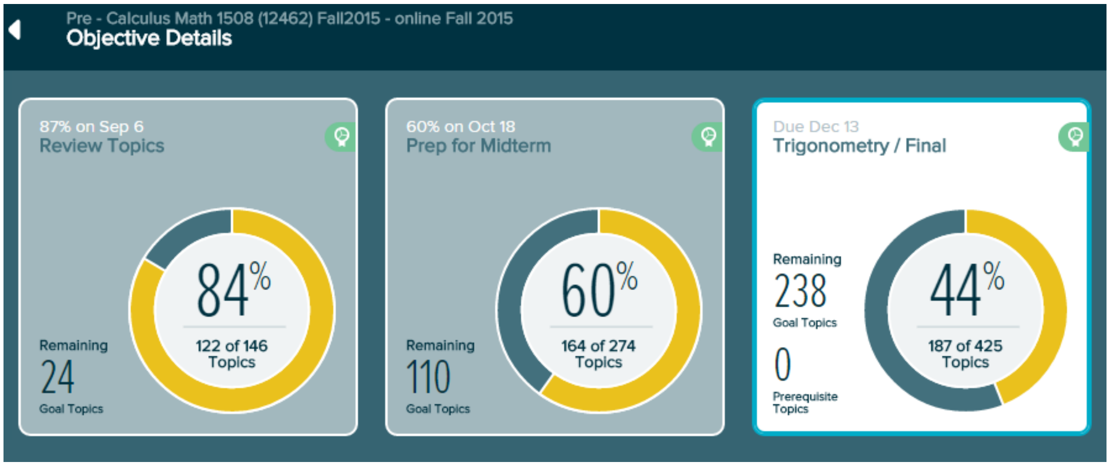
If you are a military student with the potential of being called to military service and /or training during the course of the semester, **you must contact me as soon as possible before you leave**.

Course Schedule:

After logging onto ALEKS, uploading the appropriate plug-ins and completing the tutorial, students must complete their initial knowledge check by September 2. If the

initial assessment is not completed by September 2**, you will be dropped from this course.**

Students must work on ALEKS a minimum of 8 hours per week. If you do not maintain 8 hours per week you may be dropped from this course. There are three objectives. Review Topics, Prep for Midterm and Trigonometry.



The Review Topics objective is due on September 2. The more topics you complete the better your grade will be. For example, the picture above shows 122 out of 146 topics completed is a grade of 84%.

The Prep for Midterm is due October 7. You want to complete as many topics as you can before this due date. The example above, show 164 out of 274 topics were completed by the due date, so that grade is a 60%.

NOTE: Some of the topics overlap, so some topic will count for more than one objective.

An online ALEKS, Midterm Exam will appear on Sunday, October 9 at 12:01AM and close on Sunday, October 9 at 11:59PM. You must login to ALEKS 2 hours before the exam closes. This will be a 2 hour 15 question exam on ALEKS, once you click on the exam you the timer does not stop.

The Trigonometry objective is due on December 9.

A Final exam will appear Wednesday December 7 at 12:00 PM (noon) and close on Thursday December 8, at 11:59 PM.   You must login to ALEKS 3 hours before the exam closes. This will be a 3 hour 20 question exam on ALEKS.
Good Luck: This is a challenging class, but if you put the time in each week, you will learn and be well prepared for calculus.

Appendix F

Demographic-Survey

1. What is your age?

17 yrs or younger 18 yrs – 20- yrs 21 yrs – 23 yrs 24 yrs – 26 yrs over 26 yrs

2. What is your gender? Female Male Other

3. What race/ethnic group do you typically identify with?

African-American/Black Asian American Caucasian

Hispanic/Latino Native American Other(s)_______________

4. What language do you speak most often at school?

English Spanish Both other

5. What language do you speak most often at home?

English Spanish Both Other

6. What language do you read most often?

English Spanish Both Other

7. What language do you write most often?

English Spanish Both Other

8. How often do you use the internet to translate words you do not know the meaning to?

Never Rarely Sometimes Quite Often Very Often

9. How many years of your education prior to college were in English?

0 years 1-2 years 3-4 years 5 – 6 years 7 – 8 years over 8 years

10. How many years of your education prior to college were in Spanish?

0 years 1-2 years 3-4 years 5 – 6 years 7 – 8 years over 8 years

11. How many ESOL or ESL classes did you take in elementary school?

Never taken an ESOL or ESL class   1-2 classes   3-4 classes   5-6 classes   over 6

12. How many ESOL or ESL classes did you take in high school?

Never taken an ESOL or ESL class   1-2 classes   3-4 classes   5-6 classes   over 6

13. How many ESOL or ESL classes did you take or are currently taking in college?

Never taken an ESOL or ESL class   1-2 classes   3-4 classes   5-6 classes   over 8

14. Have you ever taken a math class taught in Spanish only? If yes, for how many years?

Never attended   1-2 years   3-4 years   5 – 6 years   over 6 years

15. How often do you think in Spanish when you work on math problems?

Never   Rarely   Sometimes   Quite Often   Very Often

16. How often do you think in English when you work on math problems?

Never   Rarely   Sometimes   Quite Often   Very Often

17. How often do you think in both English and Spanish when you work on math problems?

Never   Rarely   Sometimes   Quite Often   Very Often

18. Do you think your language skills in Spanish will be important to your career after college?

Extremely Important   Very Important   Neither Important nor Unimportant

Very Unimportant   Not at all important

19. Do you think your language skills in English will be important to your career after college?

Extremely Important   Very Important   Neither Important nor Unimportant

Very Unimportant   Not at all important

20. How often do your translate math homework in your mind in order to understand the assignment?

Never   Rarely   Sometimes   Quite Often   Very Often

Appendix G

Mathematical Self-Efficacy Scale: MSES

MATHEMATICS SELF-EFFICACY SURVEY

Mathematics Self-Efficacy Survey (Betz & Hackett, 1989) range from 0 – 9.

0-No Confidence at all Very little Confidence Some Confidence
Much Confidence 9-Complete Confidence

Part I: Everyday Math Tasks
How much confidence do you have that you could successfully?

1. Add two large numbers (e.g., 5379 + 62543 in your head.
2. Determine the amount of sales tax on a clothing purchase.
3. Figure out how much material to buy in order make curtains.
4. Determine how much interest you will end up paying on a $675 loan over 2 years at 14 3/4% interests.
5. Multiply and divide using a calculator.
6. Compute your car's gas mileage.
7. Calculate recipe quantities for a dinner for 3 when the original recipe is for 12 people.
8. Balance your checkbook without a mistake.
9. Understand how much interest you will earn on your savings account in 6 months, and how that interest is computed.
10. Figure out how long it will take to travel from Columbus to Chicago driving at 55 mph.
11. Set up a monthly budget for yourself taking into account how much money you earn, bills to pay, personal expenses, etc.
12. Compute your income taxes for the year.
13. Understand a graph accompanying an article on business profits.
14. Figure out how much you would save if there is a 15% mar-down on an item you wish to buy.
15. Estimate your grocery bill in your head as you pick up items.
16. Figure out which of 2 summer jobs is the better offer: one with a higher salary but no benefits; the other with a lower salary but with room, board, and travel expenses included.
17. Figure out the tip on your part of a dinner bill total split 8 ways.
18. Figure out how much lumber you need to buy in order to build a set of bookshelves.

Part II: Math Courses
Please rate the following college courses according to how much confidence you have that you could complete the course with a final grade of ―A‖ or ―B‖. Circle your answer according to the 10-point scale below: [note: same scale as Part I]

19. Basic College Math

20. Economics
21. Statistics
22. Physiology
23. Calculus
24. Business Administration
25. Algebra II
26. Philosophy
27. Geometry
28. Computer Science
29. Accounting
20. Zoology
31. Algebra I
32. Trigonometry
33. Advanced calculus
34. Biochemistry.

Appendix H

Mathematics and Technology Attitude Scale

Mathematics and Technology Attitudes Scale
Developed by Robyn Pierce, Kay Stacey and Anastasios Barkatsas

Directions: This is a survey regarding your opinions about mathematics and technology. If at any time you do not feel comfortable answering any of the questions, you do not have to. This survey is completely voluntary and anonymous. This survey is printed on the front and back.
Please check the box that best matches your opinion on the statements be

Hardly ever Occasionally About half the time Usually Nearly always

1. I concentrate hard in mathematics.
2. I try to answer questions the teacher asks.
3. If I make mistakes, I work until I have corrected them.
4. If I can't do a problem, I keep trying different ideas.

Strongly disagree Disagree Not sure Agree Strongly agree

5. I am good at using computers, tablets and/or smart phones.
6. I am good at using things such as Facebook, Twitter, Wikipedia, YouTube and/or other types of social media.
7. I can fix a lot of computer problems.
8. I can master any computer program needed for school.
9. I have a mathematical mind.
10. I can get good results in mathematics.
11. I know I can handle difficulties in mathematics.
12. I am confident with mathematics.
13. I am interested to learn new things in mathematics.
14. In mathematics you get rewards for your effort.
15. Learning mathematics is enjoyable.
16. I get a sense of satisfaction when I solve mathematics problems.
17. I like using multimedia technology for mathematics.
18. Using multimedia technology in mathematics is worth the extra effort.
19. Mathematics is more interesting when using multimedia technology.
20. Multimedia technology helps me learn mathematics.

Appendix I:

Summary of studies examining effectiveness of ALEKS.

2003-2012	Author and year	Students (college or high school)	course	Participants (N), ALEKS Intervention group (AI), control group (CG)	Effectiveness	Intervention class format
Increase in grade or placement	Barrus, Sabo, Joseph, & Atkinson (2011)	high-school seniors	Algebra	N=30	Increased Accuplacer scores ANOVA (p<0.01)	4-hour class meeting in computer lab with teacher to answer questions
	Fine, Duggan, & Braddy, (2009).	high-school seniors	Intermediate Algebra	N=67, AI=32, CG=35	Removed Remediation, Paired t-test (p<0.01)	one semester class during senior year in computer lab with teachers
	Hagerty, G., & Smith, S. (2005)	College students	College Algebra	N=251, AI=132, CG=119	1) Increase on pre- and post-test, t-test (p<0.01) 2) Skill retention ANOVA (p<0.01)	lecture class with ALEKS for all assignments
	Hagerty, Smith, & Goodwin (2010)	College students	College Algebra		1)Increase in nationally normed test (CAAP) ANOVA (p<0.01) 2) Increased pass rates for college Algebra 3) Increase in enrollment in Trigonometry	1 class session/week in computer lab with tutors 1 class session/week had cooperative activities
Increase was not statistical significant	Callahan, Chyung, Guild, Clement, Guarino, Bullock, & Schrader, (2008)	College students	Pre-Calculus	N=125, AI=88, CG=37	Students improved Pre-calculus knowledge based on pre- and post-test, Wilcoxson signed ranks test (p<0.001)	ALEKS used as weekly homework
	Hampikian, Guarino, Chyung, Gardner, Moll, Pyke, & Schrader (2006)	College students	Pre-Calculus engineering course	N=212, AI1=17, CG1=101, AI2=31, CG2=63	increase grades and pass rate; not statistical significant	3 hours spent in computer lab out of a 5.5 hour course with mini-lectures
	Hampikian, Guarino, Chyung, Gardner, Moll, Pyke, & Schrader (2007).	engineering students	Pre-Calculus engineering course	N=121, AI=37, CG=84	mean math scores increased, not statistical significant	most of 5.5 hours spent on ALEKS
	Hrubik-Vulanovic (2013)	college students	Remedial Math	N=130	1) scores on final exam same for ALEKS and non-ALEKS students, positive result	Emporium format, students had to seek Instructors help
	Reisel, Jablonski, Hosseini, & Munson (2012)	Incoming College Freshmen	Summer Bridge	N=102	ACT scores improved	computer lab with instructors

No significant difference in grades or placement	McClendon & McArdle (2002)	community college	Elementary Algebra - self selected	N=147, AI=49, CG1=46, CG2=52	no significant increase in grades Chi-squared test(p=0.376)	No lecture, ALEKS is stand alone
	Spradlin and Ackerman (2010)	University students	Intermediate Algebra	N=100, AI=42, CG=58	no significant increase in grades ANOVA (p=0.128)	traditional class with ALEKS as supplement
	Stillson, & Alsup, (2003)	University students	Basic Algebra	N=59	no increase in passing grade when compared to previous semesters	traditional lecture and textbook homework with ALEKS as supplement
	Xu, Meyer, & Morgan (2009)	Graduate students	Graduate Statistics	N=86, AI=41 (fall 2006) and CG=45 (fall 2005)	no-significance t-test (p-.20) and ANCOVA (p<0.01)	Hybrid class with ALEKS as homework

Appendix J

Examples of Course Forum Questions

Week 3: How do you feel about your initial assessment in the program ALEKS? [¿Cómo sentís hasta ahora acerca de su evaluación inicial y el programa en ALEKS?]

Week 4: If you changed the ALEKS program into Spanish, explain how this affected your understanding of the topics. [Si ha cambiado el programa ALEKS en español, explicar cómo esto afectó su comprensión de los temas]

Week 5: How often did you use an online translator to understand the instructions for each topic? Please attach a screen shot of the word(s) you translated. [¿Con qué frecuencia ha utilizado un traductor online para comprender las instrucciones de cada tema? Por favor, adjunte una captura de pantalla de la palabra o palabras que usted tradujo.]

Week 6: What takes the most time when you are working on ALEKS? The math problems? Understanding the instructions? Reading the explanations? Language? Please explain in detail. [¿Qué necesita más tiempo cuando están trabajando en ALEKS? ¿Los problemas de matemáticas? ¿Entender las instrucciones? ¿Leyendo las explicaciones? ¿Idioma y lengua? Por favor explique en detalle.]

Week 7: When you are working on the topics do you think in English or in Spanish or both? Please give as much details as possible. [Cuando se trabaja en los temas ¿crees en inglés o en español o en ambos? Proporcione tanta información como sea posible.]

Week 8: Did you change the ALEKS to Spanish while taking the midterm exam? If you did please explain why you decided to change the language. [¿Cambió el ALEKS al español mientras esté tomando el examen de mitad de período? Si por favor explicarnos por qué decidiste cambiar el idioma.]

Appendix K

Example of Participant's course forum posts for fall 2014

	Forum Questions	**How do you feel about your initial assessment? ¿Qué piensas acerca de su evaluación inicial.**	**Describe your experience with the ALEKS program this week. Describa su experiencia con el programa ALEKS esta semana.**	**did you change the midterm to Spanish**
Fall 2014	Anna	La evaluación inicial fue un reto porqe como estudiante de nuevo ingreso el curso online es algo confuso, me hizo darme cuenta de lo importante que es el manejo del tiempo. También me hizo recordad algunas cosas que había olvidado. The initial assessment was challenging because as a freshman the **online course is a little cofussing**, and made me realize how important is the **time management**. Also it made me remember some things that I had forgotten.	This week was hard because I had very much topics to review and make my objective smaller, the hours wasn't a problem because I over worked in hours this week. Esta semana fue algo dura ya **que tenía muchos temas que revisar** para ir al corriente con mi objetivo, las horas no fueron un problema ya que acabé con ellas exitosamente y hasta hice más.	I Did not change the midterm to Spanish. Besides I do not know how to do it, I prefer to take the course all in English, in that way I can learn about specific words in English and be prepared
	Angelica	I already knew the majority of the topics, but I have forgotten some details that made me have wrong answers. I have been getting used to the program and it has helped me remember.	This week has been a little troubleling. I need **more time** to complete each of the topics, and I cannot fullfill my personal goal of topics per day because of that. But I will do extra effort to cover that	
	Marco	it was helpful but so confussing at the same time. I recommend to	This week is very hard for me because the subjects are	was in spanish already

		make a tutorial of how to use it.	getting more harder and harder and it take more time that i usually do. i already advance a lot a think i will be ready to do the midterm earlier	
	Oscar	the initial assesment made me realize i forgot a lot of simple and necessary concepts of math	Aleks program this week has been harder, i need to spend more time and dedicate more in the topics;its getting harder. i advance quite a lot this weekend but i think i need to dedicate more because im missing a lot of topics for midterm	(PT-PARTIALLY TRANSLATED) i changed midterm to spanish becuase one of the topics i learned it in spanish but i was getting confused when translating it to english.

Appendix L

Example of Course Forum Posts Analysis

		did you change the midterm to Spanish	**Open coding**	**codes & themes**	**Tensions**
Fall 2014	Anna	I Did not change the midterm to Spanish. Besides I do not know how to do it, I prefer to take the course all in English, in that way I can learn about specific words in English and be prepared	did not change ALEKS		Importance of learning English
	Marco	was in spanish already		Translated ALEKS for meaning making.	Lack of Spanish academic language skills
	Oscar	(PT-PARTIALLY TRANSLATED) i changed midterm to spanish becuase one of the topics i learned it in spanish but i was getting confused when translating it to english.	Translated Midterm. Changed only for one or two problems.	Meaning making of mathematical terms. Making cognitive connections in both languages	Lack of Spanish academic language skills

Appendix M

Example of Daily logs

	Time logged in	Translate ALEKS to Spanish	Did you use an internet Translator (take a screenshot)	Click on Explain button in ALEKS	Did you take an assessment?	Time logged out	did you work with a tutor?	did you google the practice problem? (take a screen shot)
8/31/2015-example		yes/no	y/n (# of times)	y/n (# of times)	y/n		y/n (# of hours)	y/n (# of times)
Participant 1								
11/16/15								
11/17/15								
11/18/15	7:30 PM	yes	no	yes	no	21:55	yes 2 hours	no
11/19/15								
Participant 2								
11/16/15	8:00	no	no	y 6 times	no	10:00 AM	no	no
11/17/15	8:00	no	no	y 3 times	no	8:45	no	no
11/18/15	6:00	no	no	y 13 times	no	10:00 PM	no	yes
11/19/15	8:00	no	no	y 2o times	no	21:30	no	no
11/20/15	0:00							
11/21/15	0:00							
11/22/15	7:04	no	no	yes 20 times	no	8:56	no	no
11/23/15	9:27	no	no	yes 15 times	no	10:47	no	no

Appendix N:

Sample of email questions

First set of email questions:

Did you go to a private school in Mexico?
Did you take a bilingual Algebra class?
When you do not understand a word in English, how do you find the meaning of the word online?
Is it important for you to learn math in English? Please explain in detail.
If you took another online course would change it to Spanish if you could?

Asunto: Por favor responder lo más posible.

1. *¿Fuiste a una escuela privada en México?*
2. *¿Hiciste una clase bilingüe de álgebra?*
3. *Cuando no entiendes una palabra en inglés, ¿cómo encontras el significado de la palabra en línea?*
4. *¿Es importante aprender matemáticas en inglés? Por favor explique en detalle.*
5. *Si usted toma otra curso en línea ¿cambiarlo a Español Si pudieras?*

Second set of email questions:
Do you use a dictionary, book, or a Dictionary online? Do you feel that using a dictionary helps you learn math better? Can you explain how using Dictionary.com helps you learn math better or faster. What is most important for you, learn math in English or learn math in any language?
¿Usas un diccionario, libro, o un diccionario en línea? ¿Sientes que utilizando un diccionario te ayuda aprender matemática mejor? Puede explicar cómo usando Dictionary.com te ayuda aprender matemáticas mejor o más rápido.
¿Qué es más importante para ti, aprender matemática en inglés o aprender matemática en cualquier idioma?
Third set of email questions:
Do you use Google Translate? Can you explain how you feel about learning math in English and how you feel when you translate a word into Spanish to help you with math?
¿Utilizas Google Translate?
¿Puede explicar cómo se siente sobre el aprendizaje de las matemáticas en inglés? ¿Y cómo se siente al traducir una palabra en español para ayudarle con las matemáticas?

Appendix O:

Sample Transcriptions of face-to-face interviews: Gracia

Me: Ok, no más quería preguntarte unas preguntas de que hico usted en este curso. En unos de los coreos pusiste que “es importante aprender en inglés.”
G: Mm Hmm
Me: En este curso, porque en matemáticas era importante para ti aprender en inglés?
G: Porque en matemáticas?
Me: Si
G: Pues porque…pues es un…en inglés el matemática las vamos aprender porque es un idioma que tenemos que hablar, o sea, vas aprender…venimos a los estados unidos tenemos que aprender la idioma ingles. Entonces obviamente pues tenemos que aprender matemáticas también igual en el mismo lenguaje.

Me: Piensas que vas a tener una carrera aquí en los estados unidos o en México?

G: aquí

Me: Si?

G: Mm Hmm

Me: Quien te dijo o como aprendes que necesitas aprender inglés para su carrera?

G: Pos porque, pos aquí, aquí es donde quiero a ser toda me carrera, no. Entonces el idioma que se habla pos es en inglés. Y lo necesito (clears throat). Como yo no me sé todo el inglés. Yo estudie nada más une año en Neuvo, un año y medio en Nuevo México y aprendí poquito. Entonces, yo iba estudiar en la, en la UACJ, Universidad Autónoma de Ciudad Juarez. Pero, pues no, se a yo entendí que tenía que yo, que yo tenía venir, venirme paraca, porque acá nací, y acá…o se a, si yo quiero una carrera, yo pienso…yo piense siempre así porque así sería mejor aser una carrera.

Me: Mm hmm, OK

G: Entonces, me devolví de a ha, pues me perdí de hecho un beca que yo tenia a ha. Me han dado una beca en la UACJ, entonces me ofrecieron trabajo acá, yo dejo no dije prefiero dejar un ano la escuela, no entro a la UACJ, me vine paraca para, para el, para El Paso, y luego, aquí empecé trabajar un ano. Ya empecé a trabajar un ano y tuve me direcciónito aquí. Y fue cuando metí beca para meterme aca en UTEP.

Me: Ok. Cuando no entendiste…aver, deje me ver que me dijiste. Usaste un diccionario cuando no entiendes una palabra

G: A ha

Me: Has usado un “Dictionary online”, como Google translate o…

G: Google translate a veces

Me: a veces si lo haces?

G: A ha.

Me: Y también dijiste que, “Por lo regular si no entiendo algo repaso el procedimiento muchas veces. Si ya de plano no entiendo busco en internet.” El procedimiento es el “Explain button” en ALEKS?

G: A ha. Lo que me explica.

Me: Mm Hm

G: Y luego por ejemplo leo una explicación, y luego no lo entiendo. Y pues me voy a la otra, ya ve que siempre parece para que tener otra.

Me: Mm Hmm, Mm Hmm.

G: Y la vuelvo hacer. Y luego, todo lo copiaba en un cuaderno, o sea me ponía apuntar para ya si no lo entendía lo volvía a poner, y luego, ya al último cuando tenía varias así explicaciones, este ya me ponía otra y ya solo resolvía con esas que ya a tenia apuntada.

Me: Ah, Ok. Y lo combais a ALEKS a ingles, patras a ingles para ver como

G: No, no

Me: como se ace…

G: Agá de cuenta de que, al mero principio que que puso ALEKS intente contestar unas cosas en ingles, entonces, me, me…o sea no le entendía mucho y eran de usar Google Transate o usaba un diccionario para ver verdad. Pero pos también hay veces que, que perdia tiempo en aser eso. Porque pos come no se mucho ingles y luego ya ve que son ocho oras y una vez no alcanzaba completar por el trabajo y todo eso. Entonces decía no pues mejor lo pongo en español, porque voy estar batallando mucho en estar, pos si en estar traduciendo y todo. Y si pos, por eso fue el motivo que lo combie mejor a español. Y ya asi me, me aquede.

Me: Ok, entonces cuando lo ases en español, como como sientes que vas a usar en calculo uno? O necesitas calculo uno?

G: no tengo ideo, pero yo…no se? Toda vía no me, no me dijeron si necesito calculo uno.

Me: estas tomando clases en…que va seguir después de precalculo?
Grisel shakes her head and shrugs her shoulders.

Me: A no sabes.

G: no se

Me: Estas tomando clases en ingles a horita?

G: Si, pos todas las de ESOL. Todas esas las estoy tomando. Ahorita ya, vamos agarrar la…ya tengo que garrar la ultima, una esta semestre, pero como estoy debajo del colegio de Liberal Arts, tengo que agarrar otra en que es la 2311 creo. Y luego sea la otra semestre toda via voy a tener otra.

Me: Oh. Y tienes clases de science?

G: No

Me: No? Ok. Tienes difícil, en esas clases come te va? Estas viendo bien?

G: Si pero es que esas clases, son..solo tuve una clase, las únicas clases en ingles que tuve son las, dos de ESOL, entonces si nos nosotros no entendemos algo nuestra maestra nos explica en español.

Me: Mmm

G: Entonces, Ya en mi próximo semestre si van a ser clases mas difíciles porque por ejemplo tengo Criminología, y luego tengo, voy a tener biología. Y esas clases ya, ya me, la advisor me dijo, dijo ya para estas clases ya dijo ya nada va a ser fácil. Dijo porque ya son todas en ingles.

Me: Si

G: Dijo, ya lo que tu no entiendes ya vas a tener que búscalo lo que es todas porque ya no van hacer como las otras.

Me: Si si así es. Y los videos, No buscaste videos en en online?

G: Yo si, pero en español.

Me: Si en español. Quando los buscas en español, as notado que hay videos que son de, pos es como si yo puse un video

G: A ha, es gente normal que no mas como te esta explicando ahí.

Me: Si, pero que no saben español muy bien, a la mejor no bien, pero…es que note un video que decía SOH CAH TOA. Sabes que es SOH CAH TOA?

G: No

Me: Ok, note un video que decía que decía eso, Y como como Que piensas cuando ves los videos y notas que no te va ayudar? Porque no no, el español no esta bien? Si notas eso?

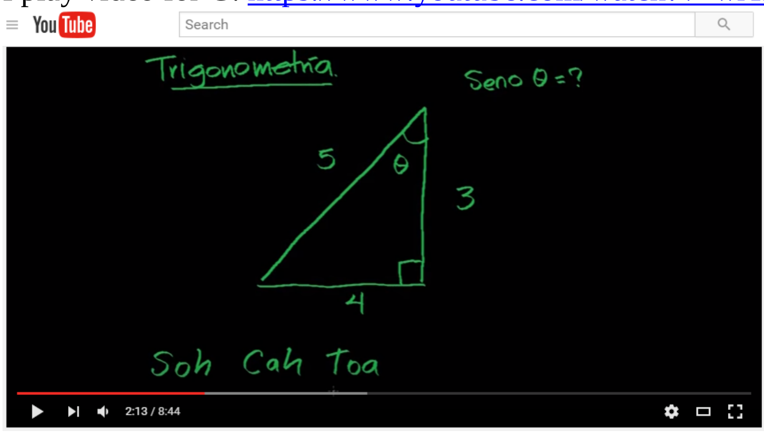
G: Si.

Me: y como lo notas?

G: Pos es es como lo hablan. Porque muchas veces hablan, porque muchas veces pueden hablar, pueden no saber español pero pueden, o sea se les entienden la palabra. Si me esplico? O se no lo saben much pero lo lo hablen poquito y y en que lo hagan dicho Pocho o lo hagan dicho mal, si le entiendes poquito pero hay otros que de plano pos no.

Me: Ok. Porque esta es la que te digo, mira.

I play video for G. https://www.youtube.com/watch?v=wA13cK9x8wI



Me: Si la puedes ver?
G nods
I stop the video here to ask her what she thinks of this video?
Me: que piensas de este?... Parece bien? Si es algo que…
G: Pos nomas me parecido un poquito asi como aborujado lo…Como explico lo de trigonometría
Me: Mm hm
G: Esta asi como, como que esta diciendo como lo mismo
Me: Ah ok. Y si, Y si le picas a este video y ha como dijiste que sentiste come que algo estaba raro
G: Mm hm
Me: lo cambias
G: Si
Me: Y buscas otro?
G: Si, de bolada.
Me: ok, déjame ensenarte algo mas. A ver qual es?
I foward the video to the part that says SOH CAH TOA.
Me: Has oído eso?

G: No,
Video continues for a few minutes.
Me: Eso nunca has ojudo?
G: No
Me: ok. Entonces, Es que, cuando le picas a un video entonces si notas que [te va ayudar?]
G: Mm Hm
Me: algo no está bien.
G: Si o sea lo quito. O si no veo, O si, O si, porque a veces pos quieres saber, por ejemplo, llegar buscar lo de ángulos coterminados, Y luego punes ahí y luego, le das ‘click’ y lo ves, entonces no es lo que tú necesitas. Entonces lo quitas y no más.   Si porque es que de ángulos coterminados van a venir muchas cosas, o sea pero no, no específicamente lo que tu quieres. Entonces tienes que buscar una mas.
Me: Y cómo te ayuda los videos? Puedes explicar eso?
G: Como me ayudan los videos. Porque, por ejemplo hay veces que pos a mí me gustan mucho las explicaciones asi mas en como por internet. Me gusta mas eso. Pero muchas de las veces, este hay cosas que si son une poquito mas complicadas y nos las entiendo bien. Entonces a veces ciento como…como si…a como si…alguien me explique come que…o sea con palabras no con…no con no conocían pero palabras osea outloud no escritas, verdad. Como que si puedo…entenderlo mejor.
G: Porque muchas veces me pasaba que me pasaba cuando yo cuando yo estaba en la prepa en Juarez. O sea la maestra daba su explicación si no lo entendía. y luego alguien me decía venga Grisel explícame está a ver si si te entiendo. Y yo les explicaba y me entendían mas.
Me: Mm Hmm. Y Notaste que faltaba eso en un curso de línea, online
G: Nada más en unas preguntas que se me asían difícil…solo en unas, porque no en todo, porque casi en todos si…yo entendía muy bien las explicaciones.
Me: Ok. All right. [*Finding question in my notes*] Puedes pensar en otro ejemplo en donde necesitabas a encontrar alguien o un tutor o alguien para ayudarte con las, no las temas peros las de matemáticas que necesitabas a buscar algo?
G: No, [inelligible] Yo creo que no mas eso
Me: No, Vas a tomar otro curso en línea online?
G: Pues tengo, es que hay unos…lo… como de las clases que voy a tomar pero son de biología, entonces las dos clases que me recomendó la ‘advisor’ **las dos [emphasized]** son normal. El seria uno que es la clase, y sería otra de laboratorio. Entonces yo estaba pensando que no se si me convenía agarrar las online.
Me: Porque
G: Pos porque…no se, o sea se me figura, como van hacer clases que… yo no se mucho ingles,
Me: Mm Hmm
G: Entonces, van hacer clases, no se si, la clase que estamos no se me ase tan difícil, pero se me ase o sea raro pensar biología laboratorio a ser lo así como online.
Me: Mm Hmm. No la ha visto so no como son esos cursos. Si A oído que los estudiantes, no que es fácil, pero que si lo pueden aser y que si aprenden mucho en el clase.
G: Si porque yo yo por eso de echo todavía no me registro en esas clases porque fui, fui a hablar con un ‘advisor’ nada más que están este el Lunes, disponerlos [arrange] otra vec, porque si. Le mande un correo, porque, o sea no, o sea ‘online’ no se como que no me convencen asi…un laboratorio biología ‘online.’
Me: Mm Hmm. Y porque decidiste a tomar esta clase en línea, online?

G: Porque, mi horario.
Me: Aha
G: Yo tengo un horario así como que, bien complicado. Tengo un horario en el trabajo que son de cinco días a la semana. Y luego, yo les doy, por ejemplo a mi jefe yo le doy mi horario, así que voy a escoger de UTEP. Pero, también tengo que escoger un horario fácil, para poder trabajar. Porque no, a veces no podia, como yo escoge a. Lunes, Martes, este, este semestre fue asi. Lunes, Miércoles y Viernes, y yo venía de once y media a dos veinte. Entonces, Lunes Miercoles, y Viernes yo no entraba temprano, a trabajar. Entonces, une de esos tres días, el me ponía de las tres de la tarde esta cerrar. Ya hasta lo que es las once de la noche.
Me: Mm
G: Entonces ya, ya cuando llegó ya, el siguiente, y, pos llego bien tarde a mi casa. Y luego toda vía a veces no me alcanzaba tiempo para estar revisando y todo eso o tenia sueno. A veces me quedaba dormida ahí la computadora en un lado de mí, por nada.
Me: Si
G: Y mar…, y mar…, lo que era Martes, Jueves, entonces yo no tenía descansos a domingo, o sea tengo que trabajar sábado y domingo siempre pos por la escuela. Pos par tener… pos si, pos también necesito horas, verdad, en mi trabajo. Entonces trabajaba Martes…Martes, Jueves, Sábado y Domingo. Así trabajaba. Todo el tiempo el horario que él me pusiera. Como quisiera poner ser en la tarde, será como sea. Y luego pos son ocho horas con ocho horas más o menos trabajo. Y ya de esos tres días que no venía a la escuela, me ponía a ser. Y cuando, pero cuando me ponía a cerrar, ya se me ponía bien pesado. Porque vengo, vengo por acá, y si hay mucha línea en el puente, como El Paso yendo a Juárez, y luego, hay mucha línea en el puente, y luego ya, me tenía que venirme temprano, entrabe aquí en la escuela, y luego ya a las dos veinte, a las dos veinte salí, siquiera me daba tiempo o sea yo entraba a trabajar a las tres. Salía aquí a las dos veinte, y luego a veces que me lleva en el bus, a veces me llevaba un amigo, verdad.
Me: Si
G: Pero, cuando be lleva en el bus, salir corriendo agarrar el bus, y luego horita, y entrar a las meras tres. Y luego cambiarme, porque ya venia con ropa, verdad. A si, cerrar, si se me hacía difícil.
Me: Mm Hmm.
G: [inelegible] Mi horario es como bien, bien complicados. Y por eso yo tengo que escoger un horario aquí de UTEP que…me facilite a poder trabajar también.
Me: Mm Hmm: Vas a tomar esta clase otra ves?
G: Si.
Me: en linia o..
G: Pos no, no se como
Me: cuando lo vas a tomar?
G: Pos yo creo que hasta al próximo semestre. Tengo que considerar…
Me: En el verano o en…?
G: No, en ya en el 'fall.'
Me: Ok. Si quieres. Si lo tomas otra vez 'online'
G: Mm hmm
Me: lo que va pasar… I ver si todavía lo tengo…en donde esta? [looking for G's progress report] Si puedes practicar unas cuantas horas en…con tus notas…
G: Mm Hmm.

Me: Si comienzas otra ves en, le voy a poner le asi de temas. Compensaste con el principal 'initial Knowledge check'. Cuando lo hiciste condensaste con cien temas, los hiciste bien.
G: Mm Hmm
Me: Y luego estaban subiendo subiendo, subiendo, hasta que ya sacaste cientos noventa y siete, verdad. Si lo tomas otra ves en 'online' probablemente vas a compensar como con ciento ochenta o noventa temas. Porque ya los sabes.
G: Mm Hmm
Me: Y si lo tomas asi, va estar ahí, vas a comenzar ahí, y ya no vas a tener tantas temas que aser.
G: Mm Hmm
Me: Pero, si lo vas a tener que comenzar, ya ves, vas a tener que comprar el, el la programa otra ves. Vas a tener que tomar el 'initial assessment'. Yo pienso si practicas une poquito, vas a comenzar ahí. Y luego se vas ser mas fácil.
G: Mm Hmm
Me: porque si lo tomas 'face to face', en une clase, entonces vas a tener quatro oras de, con un profesor, y vas a tener que buscar un profesor que te puede ayudar con tu inglés. Y luego dos horas de de 'workshop.' So, seis horas vas a estar en una clase. Los lunes a, lunas a…todos los días.
G: todos los días?
Me: si
G: Pos, me que me cedia mejor volver a tomarla online. Porque si, pos ya es, ya lo mejor ya se, y ya me puedo acomodar, porque también lo que pasaba es que, al…al princ…y fue… [clears throat] al principio... al pricipio de la, al principio de la, de la clase, yo también, tenía que estar aquí en la escuela. Porque había un tiempo que no tenía computadora en mi casa y luego internet y todo eso batallaba une poquito más.
Me: Si, y puedo ver que no mas tuviste quise seis horas por la semana. Y deberías de tener como cientos cincuenta dos horas total, pero ya se que estabas trabajando, y, 'you know' tenías muchas cosas. Por eso te faltaban las horas. Porque no mas era por poquito que no pasaste.
G: Mm Hmm
Me: Si lo tomas otra vez, como te digo, si practicas un poquito, vas a comenzar ya mas con cientos ochenta, algo así. Y luego se te va a ser mas fácil, porque ya no tenes tantas temas.
G: Y luego sabe que fue, también la problema que yo me, yo me fije al último, cuando fue la primera que fue al de lo principio al midterm. Yo nunca me, yo, o sea, me ponía a, a ser la, a contestar y todo eso, pero nunca, nunca me fije bien en el syllabus. O sea, que era, que era lo que tenia que aser. Nunca me fije, y nunca agarrara un clase online. Y luego cuando me fije que decía, que me iba a calificar de ahí al midterm, el Review Topics y leugo, le paracillo para el midterm y todo eso. Y yo ni anqueta. Andaba como en limbo, no nunca, nunca me fije bien.
Me: Mm Hmm. Si si. Porque, aver con esta…Si porque hiciste bien en el Review, com…compl…hiciste setenta y síes por ciento
G: setenta y síes por ciento, mm hmm.
Me: Pore a qui en el Prep, y luego en el trigonometría no hiciste tanto
G: Mm Hmm
Me: Por eso te bajo tanto tu grado.
G: Si, y eso es lo que paso. Y, y, por ejemplo, este, este curso, es lo yo quiera preguntar también. Porque por ejemplo, esta es una de las clases que voy a teñir que repetir, verdad, pos el próximo semestre.
Me: Si

G: Entonces…[clears throat] Por ejemplo el grado de esta, por ejemplo que la reprobé, es como es, o sea, se sustituye por el otro?
Me: Si
G: O porque el otro…
Me: Si, si lo tomas otra ves, entonces, si te sacas una, una A, esta no va estar en tu GPA.
G: O sea, esa no se va quedar, o sea, me lo, si me lo van a sustituye?
ME: Si,
G: Ah…O.K.
Me: porque, es la primera vez que la tomas, verdad?
G: Mm hmm
Me: Si se te va a…substitute.
G: Porque, ya ve asustado. Yo dije Aih Noo…Voy a tener una, una Efe ahí en el este, pos me va bajar…
Me: no mas la vas a tener por dos…hasta el…hasta el…hasta Desembre. Y luego, ya cuando te, cuando entramos el grado nuevo, entonces se, se, lo quitamos. Va parecer en to transcript(¿), va estar ahí, pero no lo contamos para su, para su, carrera,
G: Y eso no afecta asi como lao? No?
Me: No
G: Ah ok. Si porque, no, si estaba pensando en eso. Dije, no se me valla quedar ahí. O sea, se va ver bien feo.
Me: Yeah
G: O no, o me, iba bajar me todo el, el GPA.
Me: Mm Hmm
G: Porque, este semestre, yo creo que si es el que me fue mas mal.
Me: Si
G: Porque los otros, el GPA que tenia era de 3.05, me parace.
Me: Ok, so si te va bajar,
G: Si
Me: pero, cuando terminas el pre-calculo en el, en el ah, fall, ya se le…
G: Y usted cree, en, en, en fall si habrá la posibilidad de volver tomar así online?
Me: Si
G: Si
Me: Si
G: entonces lo buscarle de una vez, como para registrarme en la clase?
Me: Mm Hmm
G: Si, y luego de una vez.
Me: Mm Hmm
G: Si pos para registrarme de una vez, si. Tengo que comprar otra vez el…
Me: El ALEKS program
G: El ALEKS verdad.
Me: Si, Si, pero ya sabes como va a tr…ya sabes como trabaja.
G: Si pos ya ya, **Ya** ahora si ya se.
Me: Y ya sabes que lo tienes que a ser las temas…
G: Es que para dar de recuperarme del midterm a lo que fue el final, ya no, ya no
Me: ya no pudiste
G: Ya no pude.

Me: y Luego si quieres entra este, antes que te, se te cierre, entra a esto, Y luego has copias de los, de el midterm y el final para
G: Yo lo apunte todo. Yo cada vez que asía mi, me desta yo me la apuntaba en un cuaderno.
Me: Entonces, entonces si, como te digo. Agás unas cuantos problemas por semana, en el verano, y luego cuando ya regresas ya vas estar lista
G: No, si, pos para no perder la, o sea para que no se me olvide, o sea para que no se me olvide. Porque muchas veces si esta, si viendo bien las explicaciones pos se pierde más tiempo y no completo mas, mas rápido las temas.
Me: Piensas que…Si no, Si no tenías la oportunidad de cambiar lo a español se te iba ser mas difícil? Si lo tomabas…
G: Yo creo que si.
TYPING
Me: Um…OK, se me ase que es todo.
G: Es todo? OK.
Me: Muchas Gracias
G: Bueno, muchas gracias, eh. Gusto en hablar con usted profe. Buen dia.

Appendix P:

Personal conceptual view

Based on this theoretical framework, I have developed a personal conceptual view of emergent bilinguals' digital practices in mathematics (see Figure 1). A brief description of each node relating to emergent bilinguals digital practices in an online mathematics course is presented subsequently.

The first major theoretical node is Cultural-Historical Activity Theory. Analysis of the data collected using techniques from Digital literacy theory, Self-efficacy Theory, Sociocultural Theory, and Knowledge Space Theory was interpreted through the lens of Activity Theory. Activity system diagrams were developed to explicate the complex digital practices of emergent bilinguals' for meaning making in a fully online pre-calculus course. Each node depicts the multifaceted interactions between these theories in situating this study on emergent bilinguals' digital practices for meaning making into the research literature.

The second and minor node is Sociocultural Theory. Sociocultural Theory is the theory that introduced the concept that students occupy individual knowledge states of information or Zones of Proximal Development. Knowledge Space Theory was developed using constructivist theory yet incorporates aspects of Sociocultural Theory. Many studies on hybrid classes and online classes have found that intelligent tutoring systems improve math placement and test scores (Fine, Duggan, & Braddy, 2009; Golberg & Mckhann 2000; Hagerty & Smith 2005;

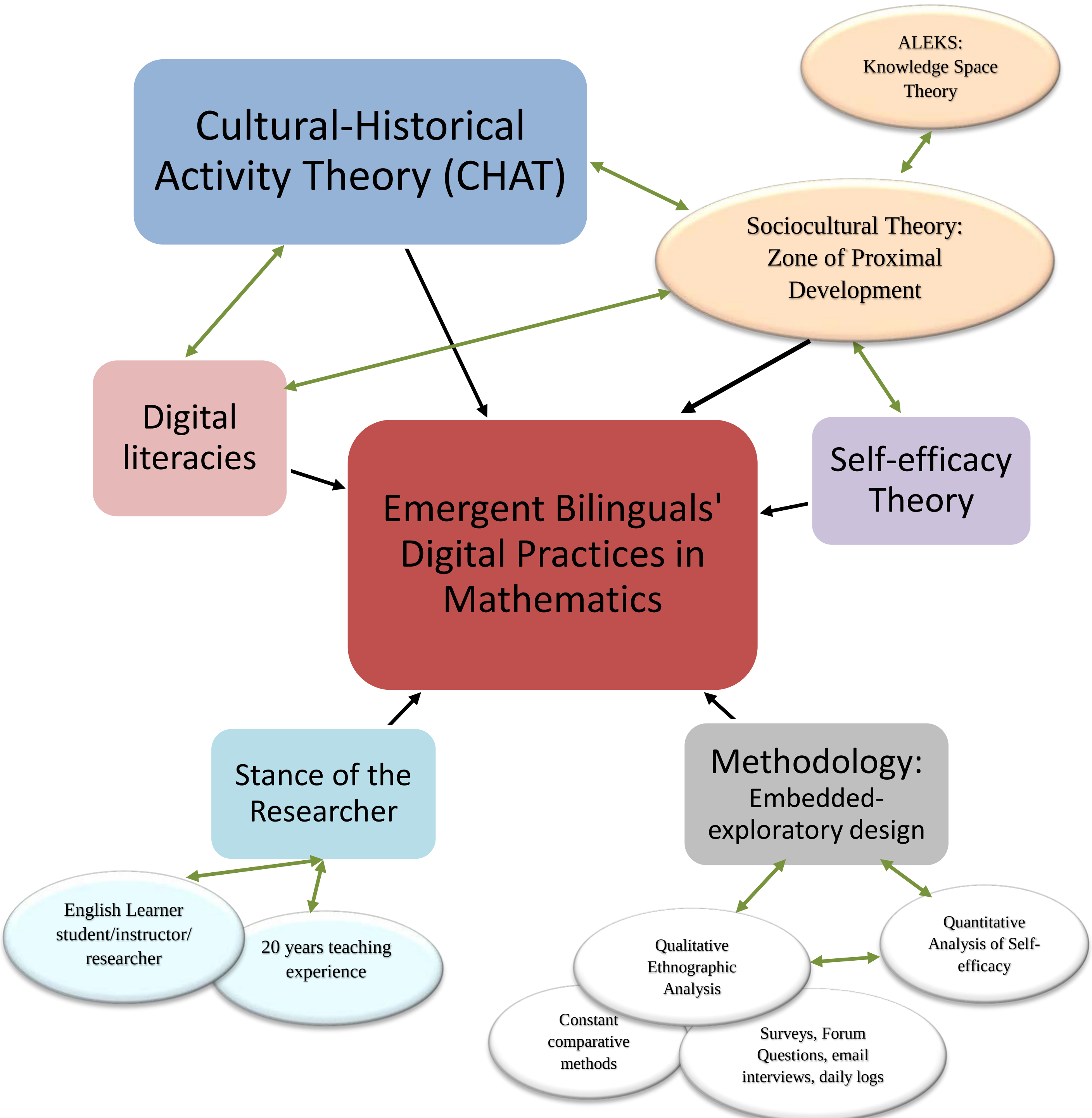


Figure 1. Researcher's conceptual view of emergent bilinguals' Digital Practices in Mathematics.

Hagerty, et al, 2010; Hampikian et al., 2006; Hampikian et al., 2007). Research on emergent bilinguals in online classes deals primarily with literacy and language acquisition (Carlson, 2007; Coryell & Chlup, 2007; Crawford, 2013). Emergent bilingual students take online classes and utilize the software in ways that have not been studied.

The third node in this study is Self-efficacy theory. Scholars have found that emergent bilinguals' self-efficacy was positively affected by connecting their culture and native language with learning mathematics (Gay, 2000; Gutierrez et al., 1999; Ladson-Billings, 2001; Moschkovich, 1999; Moschkovich, 2007, 2010). This study analyzed the correlation between a participant's self-efficacy and the translating capabilities of an intelligent tutoring system.

The fourth minor node is Digital Literacies. Emergent bilinguals come to mathematics courses with digital literacies in both their first and second language. Digital literacies amount to a skill set that allows users to relate, communicate, think and make meaning with digital media (Gillen, 2014; Gilster & Gilster, 1997; Jones & Hafner, 2012). Researchers have found that translating software into a student's native language aided in the students understanding of mathematical content thus creating digital literacies in two languages (Casas, Goodman, & Pelaez, 2012; de la Piedra & Araujo, 2012; Wang & Liao, 2011).

The final two nodes are the methodology and stance of the researcher. Through a mixed method, embedded-exploratory design, I will collect demographic, educational and self-efficacy information through pre- and post-surveys. Course forum questions will be compared and coded throughout the semester with email interviews and daily logs to find themes and key informants. Statistical descriptive analysis of time-on-topic and weekly progress reports will enhance the qualitative findings. An analysis of variance will be conducted on a pre- and post-survey analyzing self-efficacies for emergent bilinguals in an online mathematics course. As a Latino

who is also an emergent bilingual, my stance as the researcher affords me the opportunity to empathize with participants and gain their trust so they can provide truthful and in-depth information about their digital practices.

In the spring of 2010, I developed a fully online Pre-calculus course utilizing an intelligent tutoring system, ALEKS, which I have taught since its inception. It was at this time that I observed that emergent bilingual students were translating the software into Spanish in order to understand the course material. I am a bilingual student and instructor who understands the difficulties in bridging concepts between two languages. As a researcher, I will bring to light my assumptions and understanding of how emergent bilinguals engage in a mathematics course when it is delivered in an online environment.

Appendix Q:

Biliteracy continuum

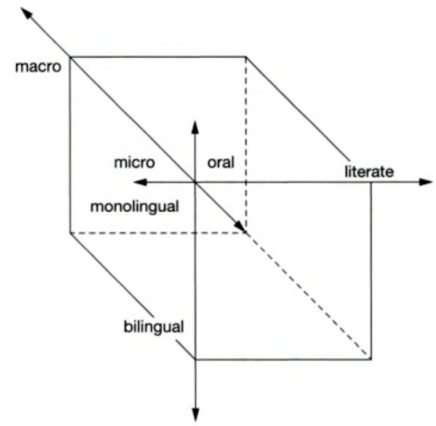


Figure 1.1 The continua of biliterate contexts

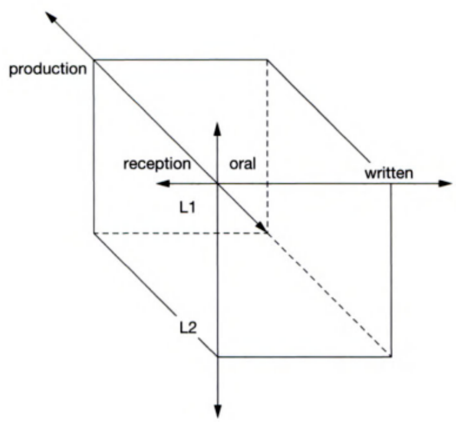


Figure 1.2 The continua of biliterate development in the individual

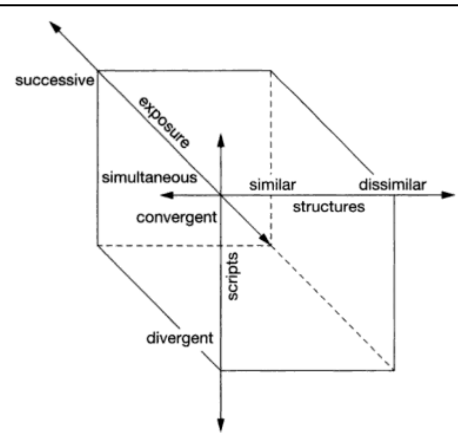


Figure 1.3 The continua of biliterate media

Appendix R:

Quatrics Cross-Tabulation fall 2014

		Do you think in Spanish when you work on math problems?						Do you translate math assignment in your mind in order to understand the assignment? If so, how...					
		Never	**Rarely**	**Sometimes**	**Often**	**All of the Time**	Total	**Never**	**Rarely**	**Sometimes**	**Often**	**All of the Time**	Total
How many years of formal Spanish education have you had?	**1 - 2 years**	50	6	5	0	0	61	35	12	3	6	6	62
	3 - 4 years	11	4	4	0	2	21	10	5	3	2	1	21
	5 - 6 years	7	2	2	0	1	12	6	3	1	1	0	11
	7 - 8 years	3	0	1	1	0	5	2	2	1	0	0	5
	over 8 years	6	7	12	7	4	36	8	7	7	10	4	36
	Total	77	19	24	8	7	135	61	29	15	19	11	135

Appendix S

Qualtrics Cross-Tabulation fall 2015

		What language do you speak most often at school?					What language do you speak most often at home?				
		English	**Spanish**	**Both**	**Other**	Total	**English**	**Spanish**	**Both**	**Other**	Total
How often do you use the internet to translate words you do not know the meaning to?	**Never**	17	0	1	0	18	12	1	5	0	18
	Rarely	28	0	5	0	33	14	9	10	1	34
	Sometimes	33	0	8	0	41	23	10	6	2	41
	Quite Often	8	0	1	0	9	4	2	3	0	9
	Very Often	4	0	1	0	5	3	0	1	1	5
	Total	90	0	16	0	106	56	22	25	4	107
How often do you think in Spanish when you work on math problems?	**Never**	63	0	4	0	67	50	1	13	4	68
	Rarely	21	0	4	0	25	5	9	11	0	25
	Sometimes	4	0	5	0	9	1	7	1	0	9
	Quite Often	2	0	2	0	4	0	4	0	0	4
	Very Often	0	0	1	0	1	0	1	0	0	1
	Total	90	0	16	0	106	56	22	25	4	107
How often do your translate math homework in your mind in order to understand the assignment?	**Never**	58	0	5	0	63	43	7	14	0	64
	Rarely	15	0	7	0	22	4	10	7	1	22
	Sometimes	6	0	2	0	8	3	3	1	1	8
	Quite Often	9	0	1	0	10	4	2	2	2	10
	Very Often	2	0	1	0	3	2	0	1	0	3
	Total	90	0	16	0	106	56	22	25	4	107

		What language do you read most often?					What language do you write most often?				
		English	**Spanish**	**Both**	**Other**	Total	**English**	**Spanish**	**Both**	**Other**	Total
How often do you use the internet to translate words you do not know the meaning to?	**Never**	17	0	1	0	18	17	0	1	0	18
	Rarely	31	1	2	0	34	31	1	2	0	34
	Sometimes	35	0	6	0	41	34	1	6	0	41
	Quite Often	7	0	2	0	9	9	0	0	0	9
	Very Often	4	0	0	1	5	4	0	0	1	5
	Total	94	1	11	1	107	95	2	9	1	107
How often do you think in Spanish when you work on math problems?	**Never**	65	0	2	1	68	67	0	0	1	68
	Rarely	22	0	3	0	25	21	1	3	0	25
	Sometimes	5	1	3	0	9	4	1	4	0	9
	Quite Often	2	0	2	0	4	3	0	1	0	4
	Very Often	0	0	1	0	1	0	0	1	0	1
	Total	94	1	11	1	107	95	2	9	1	107
How often do your translate math homework in your mind in order to understand the assignment?	**Never**	62	0	2	0	64	62	1	1	0	64
	Rarely	17	1	4	0	22	16	1	5	0	22
	Sometimes	5	0	3	0	8	6	0	2	0	8
	Quite Often	7	0	2	1	10	8	0	1	1	10
	Very Often	3	0	0	0	3	3	0	0	0	3
	Total	94	1	11	1	107	95	2	9	1	107

Appendix T

Cross-Tabulation Spring 2016

		What language do you speak most often at school?					What language do you speak most often at home?				
		English	**Spanish**	**Both**	**Other**	Total	**English**	**Spanish**	**Both**	**Other**	Total
	Never	2	0	0	0	2	2	0	0	0	2
How often do you use the internet to translate words you do not know the meaning to?	**Rarely**	6	0	3	0	9	4	2	3	0	9
	Sometimes	12	0	5	0	17	9	4	4	0	17
	Quite Often	5	1	2	0	8	4	4	0	0	8
	Very Often	1	0	0	0	1	1	0	0	0	1
	Total	26	1	10	0	37	20	10	7	0	37
How often do you think in Spanish when you work on math problems?	**Never**	21	0	2	0	23	19	2	2	0	23
	Rarely	3	0	1	0	4	1	2	1	0	4
	Sometimes	2	0	3	0	5	0	2	3	0	5
	Quite Often	0	0	3	0	3	0	2	1	0	3
	Very Often	0	1	1	0	2	0	2	0	0	2
	Total	26	1	10	0	37	20	10	7	0	37
How often do your translate math homework in your mind in order to understand the assignment?	**Never**	19	0	6	0	25	17	3	5	0	25
	Rarely	3	0	0	0	3	1	2	0	0	3
	Sometimes	3	1	2	0	6	1	3	2	0	6
	Quite Often	0	0	1	0	1	0	1	0	0	1
	Very Often	1	0	1	0	2	1	1	0	0	2
	Total	26	1	10	0	37	20	10	7	0	37

		What language do you read most often?					What language do you write most often?				
		English	Spanish	Both	Other	Total	English	Spanish	Both	Other	Total
How often do you use the internet to translate words you do not know the meaning to?	Never	2	0	0	0	2	2	0	0	0	2
	Rarely	9	0	0	0	9	8	0	1	0	9
	Sometimes	14	1	2	0	17	13	1	3	0	17
	Quite Often	6	1	1	0	8	5	1	2	0	8
	Very Often	1	0	0	0	1	1	0	0	0	1
	Total	32	2	3	0	37	29	2	6	0	37
How often do you think in Spanish when you work on math problems?	Never	21	1	1	0	23	20	1	2	0	23
	Rarely	4	0	0	0	4	4	0	0	0	4
	Sometimes	5	0	0	0	5	4	0	1	0	5
	Quite Often	0	1	2	0	3	0	1	2	0	3
	Very Often	2	0	0	0	2	1	0	1	0	2
	Total	32	2	3	0	37	29	2	6	0	37
How often do your translate math homework in your mind in order to understand the assignment?	Never	24	0	1	0	25	23	0	2	0	25
	Rarely	3	0	0	0	3	3	0	0	0	3
	Sometimes	4	0	2	0	6	2	0	4	0	6
	Quite Often	0	1	0	0	1	0	1	0	0	1
	Very Often	1	1	0	0	2	1	1	0	0	2
	Total	32	2	3	0	37	29	2	6	0	37

Appendix U

Qualtric Cross-Tabulation Fall 2016

		What language do you speak most often at school?					What language do you speak most often at home?				
		English	**Spanish**	**Both**	**Other**	Total	**English**	**Spanish**	**Both**	**Other**	Total
How often do you use the internet to translate words you do not know the meaning to?	**Never**	2	0	0	0	2	1	1	0	0	2
	Rarely	5	0	2	0	7	3	3	1	0	7
	Sometimes	4	1	3	0	8	4	2	2	0	8
	Quite Often	5	0	1	0	6	4	1	1	0	6
	Very Often	1	0	0	0	1	1	0	0	0	1
	Total	17	1	6	0	24	13	7	4	0	24
How often do you think in Spanish when you work on math problems?	**Never**	13	0	3	0	16	13	2	1	0	16
	Rarely	1	0	1	0	2	0	1	1	0	2
	Sometimes	1	0	1	0	2	0	2	0	0	2
	Quite Often	2	0	0	0	2	0	1	1	0	2
	Very Often	0	1	1	0	2	0	1	1	0	2
	Total	17	1	6	0	24	13	7	4	0	24
How often do your translate math homework in your mind in order to understand the assignment?	**Never**	11	0	2	0	13	11	1	1	0	13
	Rarely	4	0	1	0	5	1	3	1	0	5
	Sometimes	1	1	1	0	3	1	2	0	0	3
	Quite Often	1	0	2	0	3	0	1	2	0	3
	Very Often	0	0	0	0	0	0	0	0	0	0
	Total	17	1	6	0	24	13	7	4	0	24

		What language do you read most often?					What language do you write most often?				
		English	Spanish	Both	Other	Total	English	Spanish	Both	Other	Total
	Never	2	0	0	0	2	2	0	0	0	2
How often do you use the internet to translate words you do not know the meaning to?	**Rarely**	6	0	1	0	7	7	0	0	0	7
	Sometimes	7	1	0	0	8	7	1	0	0	8
	Quite Often	4	0	2	0	6	4	0	2	0	6
	Very Often	1	0	0	0	1	1	0	0	0	1
	Total	20	1	3	0	24	21	1	2	0	24
	Never	15	0	1	0	16	16	0	0	0	16
How often do you think in Spanish when you work on math problems?	**Rarely**	2	0	0	0	2	2	0	0	0	2
	Sometimes	1	0	1	0	2	1	0	1	0	2
	Quite Often	1	0	1	0	2	1	0	1	0	2
	Very Often	1	1	0	0	2	1	1	0	0	2
	Total	20	1	3	0	24	21	1	2	0	24
	Never	12	0	1	0	13	13	0	0	0	13
How often do your translate math homework in your mind in order to understand the assignment?	**Rarely**	5	0	0	0	5	5	0	0	0	5
	Sometimes	2	1	0	0	3	2	1	0	0	3
	Quite Often	1	0	2	0	3	1	0	2	0	3
	Very Often	0	0	0	0	0	0	0	0	0	0
	Total	20	1	3	0	24	21	1	2	0	24

Vitae

Julian Viera Jr.

Teaching, Learning, and Culture

Julian Viera earned her Bachelor's in Science in Mathematics from the University of Texas at El Paso in 1992. He received his Masters of Science in Theoretical Mathematics from the University of Texas at El Paso in 1994. She joined the doctoral program in Teaching, Learning, and Culture in the College of Education at the University of Texas at El Paso in 2012.

Dr. Viera is a former high school math teacher at School-aged Parent Center for the El Paso Independent School district. He then was hired as a lecture at the University of Texas at El Paso for Developmental Math in 1997. In 2009, Dr. Viera become the coordinator of Pre-calculus and Calculus I, for the Department of Mathematical Sciences. He was the recipient of the Distinguished Achievement Award in Teaching in 2011 and 2012.

Dr. Viera presented his research at the following national and international conferences: AERA annual conference 2014 and 2016; PME-NA annual conference 2013 and 2016; NCTM 2016 and 2017; NAME annual conference 2013, 2015, and 2017; NNER annual conference 2013; and FIE-EDAS 2015. He also presented his research in the following state and regional conferences: CIRCLE conference 2013; NMMATYC 2015; TxATE 2013; and Sun conference 2013.

Dr. Viera's dissertation, *Emergent bilinguals' engagement in an online mathematics course utilizing an intelligent tutoring system*, was supervised by Dr. Olga Kosheleva.

Dr. Viera will continue to serve as coordinator of Pre-calculus and Calculus I. He will be pursuing grant funding for future research. He will also be pursuing various interests connected with his research on emergent bilinguals' digital practices in online mathematics courses.

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This thesis/dissertation was typed by Julian Viera Jr.