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INTELLIGENT TUTORING SYSTEMS, PEDAGOGICAL AGENT DESIGN, AND HISPANIC ENGLISH LANGUAGE LEARNERS

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A Dissertation Presented

by

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ABSTRACT

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According to the most recent data from the National Center of Education Statistics (NCES) there were approximately 5 million English Language Learners (ELLs) in the U.S. public schools in the Fall of 2016, representing about 10% of the student population (2019). Spanish is the primary language for most ELL students, by a large margin. As a group, ELLs have faced a deeply rooted and persistent math achievement gap (U.S. Department of Education, 2015). Despite research indicating that intelligent tutors and animated pedagogical agents enhance learning, many tutors are not designed with ELLs in mind. As a result, Hispanic ELL students may experience difficulty accessing the relevant content when using a tutor. This mixed-method research investigates how a tutor can reach Hispanic ELL students, based on the social and cultural Identity framework of the Figured Worlds Theory by Holland et al., (1998). Students will socially and culturally engage with their animated pedagogical agents constructing figured worlds of learning and connection that have the power to shape the students' senses of themselves as learners of math.

This study investigates how Hispanic ELL students perceive the utility of and relate to a learning companion (LC) design. Data was examined from 76 middle school students interacting with a math tutor, MathSpring. The findings indicate that ELL students find the MathSpring LC more useful and helpful than do non-ELL students and the ELL students designed LCs that looked more like themselves than did the non-ELL students. The findings also indicate that students formed 'She/Me Connection' and 'She is Like Me' figured worlds.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

CHAPTER 1

INTRODUCTION

ELL students represent a constantly growing and diverse population. According to the U.S. Department of Education's National Center for Education Statistics (NCES) more than 4.9 million ELLs were enrolled in United States public schools in the 2016 school year which represented about 10% of the student population. They speak over 400 languages but 80% of them speak Spanish in the home (U.S. Department of Education, 2007). Of the top five most common foreign languages spoken among ELLs, Spanish ranks number one by a large margin. As a whole, ELLs lag behind in terms of academic achievement. According to the NCES only 63 percent of ELLs graduate from high school, compared with the overall national rate of 82 percent. Additionally, the National Assessment of Education Progress (NAEP) reported that in 2015 the average ELL student in eighth grade was categorized as having less than a basic understanding of the NAEP mathematics content areas (U.S. Department of Education, 2015).

Hispanic ELL students are specifically one of the most vulnerable populations of math learners in the U.S. Recent studies indicate that the educational outcomes of Hispanic students in U.S. schools lag, on average, well behind those of non-Hispanic (Reardon et al., 2009). According to Reardon et al., compared to Caucasian and Black children, Hispanic children have lower levels of school readiness at the start of kindergarten. Also, high school completion rates for Hispanic students are substantially lower than those for either Caucasian or Black students. Likewise, Hispanic students are less likely than Caucasian students to attend and graduate from college and are more likely to be enrolled in 2-year colleges than in 4-year colleges (Reardon et al.,).

Math has often been considered a universal language and more than any other subject, math skills are the top predictor for student success (Duncan et al., 2007, p. 1443). But with the language-heavy instructional methods used in the United States, such as lengthy word problems, ELLs do not have the same access to this essential and universal language. Culture influences learning styles, math symbols and concepts in addition to instructional methods.

As it happens, interactive learning environments (ILEs) such as intelligent tutoring systems (ITSs) can provide opportunities for socially situated and distributed constructivist-learning experiences and are important tools for fostering students' motivation and understanding (Mayer, 2001; Mayer & Moreno, 2003; John et al, 2009).

Research suggests that using math ITSs that feature animated pedagogical agents (APAs) may be a way to foster a positive affective relationship to mathematics. ITSs that allow students to create peer-like learning companions may support students in creating their own figured world of collaborative learning with their APA which may result in improved confidence and in a more positive attitude. These technologies are becoming more widely used in education (Kim & Baylor, 2015; Koedinger et al., 2013) and are widely recognized to have great potential for improving the way students learn (Mayer, 2001).

Problem Statement

More and more ITSs have integrated animated pedagogical agents (APAs). APAs or lifelike characters are designed to facilitate learning in ILEs. Pedagogical agents are effective tools to support student learning; they provide engagement, motivation for learning and promote positive affect states (Arroyo et al., 2009). Prior research has indicated that ITSs and APAs enhance learning (Arroyo et al., 2011, 2013; Baylor & Kim, 2015; Domagk, 2010; Graesser et al., 2004; John et al, 2013; Mayer, 2005). Graesser and colleagues (2004) reported benefits for using AutoTutor, a humanlike talking head that teaches Newtonian qualitative physics and computer literacy. AutoTutor has been evaluated in several experiments and found to produce robust learning gains for deep levels of comprehension (Graesser, 2004). Baylor & Kim (2015) report that motivational agents designed to represent a peer who modeled coping skills and encouraged the learner led to improved learner self-efficacy. They also report that the content expert agents who were designed to exhibit mastery and to provide accurate information led to improved learning outcomes for undergraduate students learning computer literacy and instructional design skills. Yet, despite research indicating that ITSs and APAs enhance learning (acquired knowledge through experience), a limitation of past empirical work is that the visual representations of the APAs was chosen by the researcher rather than the student and the APA was not provided with social cues such as facial expressions, body language and posture with which students could identify. (Moreno & Flowerday, 2005). For example, in 2012 during game-based learning research Katz & Foster (2012) discovered that "Data pointed towards a lack of racial identity in the avatars that influenced student motivation and interest in the mathematics game and by extension transformational learning." (p. 3). In this study, the students discussed how avatars used in the math-based digital game were Anglo-American, and that they did not like that feature of the game. According to Suh et al. (2011) the identity construction process is identification with one's avatar, or "the cognitive connection between an individual and an avatar, with the result being that the individual regards the avatar as a substitute self or has such an illusion" (p. 715).

Innovative instructional math technologies such as ITSs that feature APAs may help support improved math learning for ELL students because they may provide opportunities for collaborative learning and bilingual instruction and by presenting math problems visually. ITSs also allow for self-paced and directed exploration while delivering scaffolded mastery-based learning - meeting each student's learning needs, regardless of language or achievement level. Additionally, they provide data for learners to monitor their own progress and provides real-time feedback.

We need to know more about how Hispanic ELL learners may benefit from working in ITSs that feature APAs, including understanding how Hispanic ELL students relate to learning companion agent design. Such knowledge will help improve ITS learning companions and potentially have a positive impact on Hispanic ELL student affect and learning outcomes related to mathematics.

Motivation

This study analyzes student learning companion designs in the context of Holland et al.'s Figured Worlds Identity Theory framework (1998) in order to evaluate the impact of the MathSpring APA design and the student created LC designs. Based on the social and cultural Identity framework of the Figured Worlds Theory by Holland et al. the researcher hypothesized that the more a learner socially engages with their animated pedagogical agent the more likely he or she is to form a figured world (that has the power to shape the student's senses of themselves as learners of math) and be immersed in the ILE and to have a favorable or satisfactory experience.

Student created designs were analyzed because according to John et al. (2013), "Having students design characters and games, as a way to tap into their minds and establish their expectations of pedagogical characters and games is an increasingly common technique and has particularly been implemented for learning systems/games for mathematics education." (John et al., 2013).

Significance

Based on analysis of the student learning companion designs in relation to Holland et al.'s figured worlds identity theory (1998) this study attempts to provide new ITS APA design feature suggestions. The findings of this study will be used to inform improved MathSpring pedagogical agent design elements and ITS APA design in general.

CHAPTER 2

IDENTITY AND FIGURED WORLDS

This section will reflect on emerging educational discourse on Identity Theory in relation to Interactive Learning Environments (ILEs). Many researchers define the identity concept, two will be reviewed, first an overview of James Gee's (2003) four ways to view identity will be presented and then Holland et al.'s (1998) 'figured worlds' (FM) framework is discussed in detail. FWs are socially and culturally constructed through activity. This section ends with a review of concepts relating to FWs such as inter-subjectivity, identity construction, social engagement along with culture, communication and APAs.

Gee's Identities

Gee's work involving discourse and online games (2003) also indicates that a growing body of studies has reported that digital games are powerful contexts for learning because they can offer opportunities for "new experiences to immerse oneself in another world, a different identity, and through that immersion to learn both the competencies and knowledge associated with that identity" (2003).

Gee defines identity as: "Being recognized as a certain 'kind of person,' in a given context…" (2000). Gee talks about identity differences based on social and cultural views of identity and identifies four of these views, each of which are influenced by different forms of power, though they all have an effect on one another. Gee describes them as "four ways to formulate questions about how identity is functioning for a specific person in a given context or across a set of contexts" (2000). The four ways Gee establishes to view identity are the nature perspective (N-identities), the institutional perspective (I-identities), the discursive perspective (D-identities) and the affinity perspective (A-identities).

The N-identity represents an identity that people cannot control, one that comes from forces of nature, such as male or female gender assignment. While the person has no control over the gender they were born with, this identity only means something because society and culture say this biological difference is important. The notions of gender are now shifting due to activism and advocacy around human rights and the transgender movement. In the past, experiences have been shaped by a deeply entrenched gender binary, today, students live in a world where gender exists along a spectrum and gender diverse students are encouraged to live authentically.

The I-identities refers to identities set by authorities within an institution. An example of an I-identity is a student, whose identity is defined by the school as an institution with rules and traditions the student must follow. Gee claims these I-identities can be something imposed on a person, such as being a prisoner, or can be a job description for the person, such as being a college professor.

The D-identity refers to an individual trait, such as caring. D-identities are a matter of social interaction that only become identities because "other people treat, talk about, and interact" with the person in ways that bring forth and reinforce the trait. Finally, the A-identities are built by shared experiences as part of an affinity group, which according to Gee's definition is a group that shares "allegiance to, access to, and participation in specific practices"

Gee states that immersion, and the engagement engendered through gameplay, is often cited as a compelling reason for introducing game formats into the learning environment. According to Gee (2003), upon entering a gaming environment, a player adopts a character role or assumes an identity to indulge him/herself in make-believe realities and identities. Players learn through taking on new avatars' identities; the emotional attachment to the identities within the games affects learning competence and knowledge associated with that identity. Additionally, Gee proposes that by actively engaging with virtual characters, players develop "projective identities" in which their "actual identity" and "virtual character identity" are merged (2003). The boundary among these identities then becomes unclear until one cannot even recognize one's real identity. Gee believes that in virtual game environments, players can adopt, reflect on, and learn through these types of identities. Moreover, Gee argues that as players explore multiple identities, in the process they have an opportunity to learn more about multiple perspectives, as well as their own current and potential capacities and limitations.

Figured Worlds

The concept of 'figured worlds' (FWs) was first introduced by Holland et al., (1998) in their book *Identity and Agency in Cultural Worlds*. FWs is part of Holland et al.'s (1998) larger theory of self and identity drawing on Activity theory and theoretical contributions from Bakhtin, Bourdieu, and Vygotsky (Bakhtin, 1990; Bourdieu, 1977; Vygotsky, 1978).

According to Holland et al. (1998), the heart of the formulation of FWs is a person's construction of identity and its relation to activity, or in other words 'identity in practice' (p. 271). Holland et al.'s (1998), concepts of FWs, self, and identity provide a useful framework to understand identity and virtual learning environments. FWs are spaces where people 'figure' who they are through the roles, activities, and relationships that are performed in these worlds. In this sociocultural practice theory of identity and self, attention is focused on identities forming in process or activity.

The FW is the loci of where identity work occurs, where people produce and perform self-understandings within cultural activities. Urrieta (2007) draws on the work of Holland et al. (1998) to define identity as 'how people come to understand themselves, how they come to figure who they are, through the 'worlds' that they participate in and how they relate to others within and outside of these worlds' (2007).

According to Holland et al. (1998), a FW is a socially and culturally constructed realm of interpretation in which particular characters and actors are recognized, significance is assigned to certain acts, and particular outcomes are valued over others. Each is a simplified world populated by a set of agents who engage in a limited range of meaningful acts or changes of state as moved by a specific set of forces. Holland et al. reports that these collective "as-if" worlds are socio-historic, contrived interpretations or imaginations that mediate behavior and so, from the perspective of heuristic development, inform participants' outlooks. The ability to sense (see, hear, touch, taste, feel) the FW becomes embodied over time, through continual participation (Holland et al., p52-3).

One can, in the current state of technology, put on a bulky headset with connections to computers, television cameras, and data gloves and enter into a virtual reality. A FW is played out in this virtual reality; a frame becomes a world—a space and time established imaginatively—that one can come to sense after a process of experiencing. These immersive experiences with technically generated stimuli may lead to an individual's subjective psychological response of feeling the sense of presence or the sense of 'being there' (Biocca, 2003; Lombardi and Ditto, 1997).

Holland et al. broadly defines FWs as ''socially produced, culturally constituted activities'' (1998) where people come to conceptually (cognitively) and materially/procedurally produce (perform) new self-understandings (identities) (Urrieta, 2007). According to Holland et al. (1998), FWs have four characteristics. They are a cultural phenomenon to which people are recruited, or into which people enter, and that develop through the work of their participants. FWs are also social encounters in which people's positions matter. Activities relevant to these worlds take meaning from them and are situated in particular times and places. Additionally, they are socially organized and reproduced. People in them are sorted and learn to relate to each other in different ways. Furthermore, FWs distribute people by relating them to landscapes of action and by spreading one's senses of self across many different fields of activity.

According to this view, FWs are produced and reproduced through agreed-upon narratives that dramatize everyday life, but these narratives do not merely exist in the imagination - rather, through work with others in the real world, people continually produce and reproduce FWs (Holland et al, 1998). As a simplified, imagined world, a FW limits who may be included in that world, what acts may occur, and what if any changes in behavior may be allowed. In short, a FW has the power to "mediate behavior" and "inform participants' outlooks" (1998). In order to enact this controlling function, FWs rely on artifacts not only to produce and reproduce the values of that world, but also to create power and status within the world. It is through artifacts, which may take the form of an object, a person, or a discourse, that figured worlds "are evoked, collectively developed, individually learned, and made socially and personally powerful" (1998). In other words, artifacts are essential in the creation and maintenance of FWs. Holland argues that artifacts of FWs assume both a necessary material presence in the world - they are required, or at least useful, in the work of that FW - as well as an ideal presence or intentionality "whose substance is embedded in the figured world of their use"

(1998). Thus, artifacts create and recreate the FW to which they belong by having a practical usefulness in a given field or endeavor, as well as describe and reinforce an ideal vision of that FW.

Social contexts such as in-person and virtual classrooms can be understood as FWs formed through social and situated activities. These worlds are historically situated, socially enacted, and culturally constructed. They are collectivities where members "figured out" who they are in relation to each other and through a set of practices. (Holland et al., 1998; Urrieta, 2007) Within each FW students reinvent themselves by enacting different identities and engaging in sociocultural practices.

Learning and identity are strongly related. As much as learning is a process of becoming (Wenger 1998), so is identity an act of self-making. (Holland et al., 1998; Urrieta 2007) Both, identity and learning are produced in practice through life experiences. The theory of FWs is aligned with the situated perspective on learning which understands it as a social experience and activity (Lave & Wenger, 1991). When people participate in activities within particular contexts or FWs they engage in both a learning process and an identity work. (Holland et al., 1998; Urrieta, 2007). Hence, by developing shared practices, establishing relationships with others, and enacting performances of the self, students actively construct their selves as learners. However, because identities are historical phenomena, their construction processes are also embedded in both a collective past ("history-in-system") and a personal subjective history ("history-in-person"). (Holland et al., 1998; Urrieta, 2007) The "history-in-system" of learners together with the subjective "history-in-person" (socioeconomic background, educational attainment, generational status, peer groups, etc.) shape identity construction work and the participation of students. When students enter FWs they bring with them a personal subjective history of social life experiences and particular conceptual understandings that establish different possibilities of engagement and participation.

Additionally, Gee incorporates the figured worlds theory into the work of discourse analysis. In *An Introduction to Discourse Analysis*, Gee describes a FW as "a picture of a simplified world that captures what is taken to be typical or normal," one that may be unconscious or at least taken for granted (1999). Gee, like Holland et al., argues that FWs do not only exist in the mind, but externally, in the world as well, guiding and shaping human activity. For Gee, FWs define what is "appropriate:" appropriate attitudes and values, appropriate ways of acting and interacting, appropriate ways of communicating and feeling, and so on (1999). Gee describes the FW of an elementary classroom, with a female teacher in front of rows of children all approximately the same age, completing worksheets or raising their hands to answer questions. He points out that while FWs such as this classroom are often realized in the material world, the FW itself can inhibit reform efforts, as occurs when proposed educational reforms are contested because they do not conform with the established FW— are not in line with the values, attitudes, and actions that educators, policymakers, or parents hold in their minds (1999). Finally, Gee includes the analysis of FWs as a tool of discourse inquiry and argues that through the examination of discourse, texts, institutional practices, FWs reveal themselves (1999).

The framework of FWs developed by Holland et al. (1998) is used in the analysis of the impact of the MathSpring APA design and the student created learning companion (LC) designs. The FWs concept is a socially and culturally constructed identity theory that is based in activity. ITSs foster activity and interaction and those that feature APAs, that are designed sensitive to cultural norms of communication, have the potential to promote inter-subjectivity, a sense of presence, identity construction, and social engagement, which may lead to the formation of meaningful FWs of learning.

FWs are dependent on activity and interaction and correlating concepts are explored below in relation to FWs. The concepts of **inter-subjectivity** (connecting with one's APA), **identity construction** (identification with one's APA design), **social engagement** (collaborative engagement in authentic learning), **culture and communication** (communication styles or the way one reasons, feels and displays emotions, appears, and gestures is a reflection of culture), and **culture and APA's** (designing APAs consistently sensitive to cultural norms).

Inter-subjectivity

Due to the fact that FWs are socially organized and performed, they are dependent on interaction and people's intersubjectivity for perpetuation. Intersubjectivity, refers to the sharing of subjective states by two or more individuals (Scheff, 2006). In them, people ''figure'' how to relate to one another over time and across different time/place/space contexts. Holland et al. state that these ways of interacting become almost like ''roles'' but not in the static sense (1998). The significance of FWs is that they are recreated by work, often contentious work, with others; thus, the importance of activity, not just in a restricted number of FWs, but across landscapes of action.

Reeves and Nass (1997) argued that our interaction with computers could evoke a sense of intersubjectivity, encouraging us to respond to computers in fundamentally social ways, just like in human-to-human communication. Their argument can also be applied to learners' interactions with APAs, as learners could interact with APAs as in a natural communication context (Kim et al., 2007). Studies have demonstrated that collaborative learning is superior to individualistic instruction, and thus researchers have charged ahead to investigate the use of affective APAs to promote interactive learning (Atkinson, 2002). Such attempts have led to an increased support for the notion that APAs could be used to motivate learners and thus result in better learning performance and that APAs could effectively engage learners and thus increase the chances of sustained interaction.

For example, Kim and Baylor (2007) examined the impact of emotion of a pedagogical agent as a learning companion on learning and their findings indicated that the learning companion's empathetic response had a positive impact on learner interest and self-efficacy. Additionally, the research participants in Atkinson's (2002) study who worked with speaking pedagogical agents, that provided instructional math explanations both textually and verbally in addition to using non-verbal cues and gestures to help focus learners' attention, reported that the math examples that they were shown are not difficult compared with their counterparts from the group without an agent. This shows the importance of the connections between collaboration, emotional support and motivation in the learning process. Students who studied with pedagogical agents were more motivated than those who studied on their own.

Immersion and Presence

Intersubjectivity between learners and APAs in FWs is also connected to the concepts of immersion and presence. The FWs that are developed through immersive experiences with technically generated stimuli (ITSs that feature APAs) may lead to an individual's subjective psychological response of feeling the sense of presence or the sense of 'being there' (Biocca, 2003; Lombardi and Ditto, 1997).

In the early 2000s immersion and presence were often alleged as the important features of VLEs (McMaham, 2003). More recently concurring with Lombard and Ditton (2006), Dalgarno and Lee (2010) have argued that the senses of immersion and presence should not be deemed unique characteristics of VLEs; instead, they have stressed the “representational” and “interactive” distinguishing characteristics of 3D VLEs, arguing that it is essentially the representational fidelity and the interactive capability that result in the perceptual and psychological sense of presence.

Immersion

The feeling of immersion, whether physical or psychological in nature, allows the sense of belief that the user has left the real world and is now “present” in the virtual environment (Mestre, 2006). There are major schools of thought concerning the significance of the concept of immersion in a virtual environment. Witmer & Singer (1998) define immersion a psychological state characterized by the perception of being or feeling enveloped by, included in or in interaction with an environment offering a continuity of various stimulatory experiences.

From a different perspective, other researchers have suggested that immersion is more likely a product of technology that facilitates the production of multimodal sensory “input” to the user (Slater & Wilbur, 1997). Slater and Wilbur define immersion as being the extent to which a computerized system is capable of offering to the user the illusion of reality at once being: inclusive, vast, surrounding and vivid. They view immersion as the objective measurable properties of the system or environment such as technically generated stimuli that lead to an individual's subjective psychological response of feeling the sense of presence.

Presence

The notion of presence is considered to be a central attribute of VLEs (Mikropoulos, 2006). Presence is traditionally defined by the psychological perception of being “there” or "existing in" the VE in which one is immersed (Heeter, 1992; Sheridan, 1992; Steuer, 1995; Witmer and Singer, 1998). Researchers agree with the definition of presence as “the sense of being there” despite the fact that each has added his/her nuances to the definition (Mikropoulos).

Lombard and Ditton (1997) offer another explanation of the concept of presence. The authors define presence as the perceptual illusion of non-mediation. Lombard (2000) explains in a more profound manner presence as being in a psychological state of having a subjective perception in which, even if the experience is generated by technology, a part or a totality of the individual’s perception fails to recognize the role of technology at the time of the virtual experience.

Presence Factors

Based on the subjective nature of presence and the psychological perception perspective researchers have argued that immersion and presence are dependent on a range of contextual factors; including the user’s state of mind (Lomard & Ditton, 2009; Slater, 2004). The evolution of empirical research on the presence construct and the causes of presence, though inconsistent has provided empirical evidence pointing to representation vividness, interactivity and user representation characteristics as the factors that are important for influencing presence (Lombard & Ditton, 2009; Banerjee et al., 2002; Schuemie et al., 2001).

Identity Construction

The avatar serves as a tool for dynamic identity construction that allows individuals to experiment with identities and to express multiple aspects of their selves (Turkle, 1984, 1995). Individuals tend to reproduce either their real self or an improved or idealized self (Taylor, 2002; Bessière et al., 2007; Tisseron, 2009; Jin, 2010). Underlying motivations to such identity involve either a self- confirmation perspective (promotion of a positive self-concept) a compensatory perspective (distortion of negative information in a more positive way) or a self-enhancement perspective (Messinger, Ge, Stroulia, Lyons & Smirnov, 2008).

According to Suh et al. (2011), the identity construction process is identification with one's avatar, or "the cognitive connection between an individual and an avatar, with the result being that the individual regards the avatar as a substitute self or has such an illusion" (p. 715). If this connection is strong and if the individual considers the avatar his or her own self, he or she might then live the experience to the fullest, in a more immersive way. If identification can be linked to physical likeness, appearance cannot count as the only determinant of identification. For example, if individuals personalize their avatar as they wish and project their values, emotions, private self (Suh et al., 2011) and psychic self (Tisseron, 2008) in the virtual character, they are likely to identify with an avatar that does not necessarily (physically) resemble themselves.

Parmentier and Rolland (2009) argue that this identity construction is not prescribed but is set within a dynamic. They identify four dynamics: (1) duplication, in which the avatar is a loyal graphical and behavioral copy of the creator, (2) enhancement, in which the avatar is an extension that represents the more positive aspects of the creator, (3) transformation, in which the avatar really differs physically and behaviorally from the creator and (4) metamorphosis in which the avatar is a totally imaginary self, physically different and for which the creator plays a character part. Furthermore, this dynamic is part of a construction process regarding the virtual world (Parmentier & Rolland, 2009).

Context is likely to influence avatar creation and identity dynamics (Kang & Yang, 2004; Garnier & Poncin, 2009; Vasalou & Joinson, 2009; Yee et al., 2009; Suh et al., 2011; Sung & Moon, 2011), just as creation of the avatar and identity dynamics can influence the relationship (e.g., feelings, behaviors) with and within the virtual world (Yee & Bailenson, 2009; Yee, Bailenson & Ducheneaut, 2009).

Social Engagement

FWs is an identity framework that relies on social engagement. The Engagement Theory (Kearsley & Shneiderman, 1998) is a framework for technology-based teaching and learning derived from Constructivism's fundamental ideal that learning occurs when students are meaningfully engaged in activities through interaction with others and worthwhile tasks. While in principle, such engagement could occur without the use of technology, Kearsley & Schneiderman believe that technology can facilitate engagement that is difficult to achieve otherwise. The three components of this theory are **collaboration**, **project-based** teaching and learning and **authentic focus**. The three components work simultaneously to provide students with opportunities to engage in meaningful activities that motivate and inspire them.

Collaboration involves communication, planning, social skills, and project management skills in a team effort. Collaboration prepares students for the modern workplace because it forces them to explain and articulate their problems to figure out solutions and increases their motivation to learn. They have the opportunity to work with other students from different cultures with diverse backgrounds providing an added perspective and point of view. Alavi (1994) conducted a study on collaborative learning evaluating a group of graduate business students taking online classes. These students are compared to those taking classes in a traditional classroom, all of which are taught by the same instructor. The teaching/learning activities were the same for each class except the online students used VisonQuest, a groupware program, for their collaborative exercises. The findings in the post-test questionnaire indicated that the computer-based collaborative learning resulted in higher levels of skill development and self-reported learning than the traditional classroom did. Also, the test grades for the group of students who were in the computer-based classroom were higher than those of the groups of students in the traditional classroom (Alavi, 1994).

Project-based learning is a dynamic approach to teaching that lets students explore authentic problems. Students have a sense of control over their learning because they design their own projects giving them the opportunity to exercise creativity, time management, application of key concepts to a specific area, and get away from their customary stale textbook problems. Thomas (2000) has composed a review of the research on project-based learning. Research on the effectiveness of project-based learning has been conducted in elementary, middle, and high schools using standardized test scores and research on skills gained using project-based methods. Schools in areas such as Boston, Maine, Iowa, and Tennessee reported improvement scores of three to ten times larger than the score of other students in the state as a whole after adopting project-based teaching methods (Thomas, 2000).

The third component of **authentic focus** stresses how important it is that students feel like they are making a valuable contribution while at the same time learning. When students make connections to what they are learning it increases intrinsic and extrinsic motivation (Kearsley & Shneiderman, 1998). Problem-based learning (PBL), is a constructivist/situated learning theory that emphasizes collaboration and teamwork to solve relevant problems that are real and authentic to students' lives (Barron, 1998). PBL attempts to bridge the gap between schools and the real world and build deep knowledge. According to researchers (Barron &

Darling- Hammond, 2008), PBL essentially involves the following: students learning knowledge to tackle realistic problems as they would be solved in the real world, increased student control over his or her learning, teachers serving as coaches and facilitators of inquiry and reflection, and students (usually, but not always) working in pairs or groups.

In traditional PBL, the teacher's role is to act as a tutor and facilitate and scaffold learning (Barron, 1998). Though, in interactive learning environments, an APA is integrated into PBL to enhance scaffolding. Fontes et al., (2013) examined how an APA can support PBL and Faaizah & Talib (2010) looked at how to design an APA to scaffold student learning in online PBL environment. In these systems, APAs were used as an alternative approach to scaffold for PBL and support students thinking. The APA had the tutor role and guided learners on how to solve problems and acquire knowledge. The APA also delivered instructional explanations either textually or aurally, while simultaneously using gaze and gesture to direct the learners to focus their attention while solving problems. Additionally, the APA also had a motivating role, which was to making the learning experience more effective and enjoyable. Researchers found that by integrating an APA with PBL can improve attitudes and increase quality of learning. These interactive learning environments with an APAs are example of how authentic focus can be constructed in learning environment.

Vygotsky was a major contributor to the Engagement Theory. Vyotsky's (1978) constructivist theory of social development maintains that learning occurs socially and community plays a decisive role in the process of "meaning making" for a child. He believed that learning is constructed through social interaction and that social learning actually leads to cognitive development. This points away from the traditional instructionist model of education; where teachers transmit information, and students act as receptacles. In opposition, Vygotsky's theory maintains the need for active learning, creating a classroom environment in which teacher and student act as collaborators, facilitating meaning construction and proximal assisted learning for students. While teachers' tasks are altered, the part they play in the learning process is of paramount importance. Vygotsky (1978) also believed that "more knowledgeable others" (MKOs), including teachers and "more competent peers", can aid in student development (p.86). This belief underlies Vygotsky's principle of the ZPD, the zone of proximal development. Vygotsky (1978, p. 86) describes his idea of the Zone of Proximal as "the distance between the actual development 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" In simpler terms, a student can perform a task under adult guidance or with the help of a peer that could not be achieved by him/herself.

Vygotsky argued that what children can do with the help or aid of others highlights the capabilities of their mental development better than if they were working alone (Vygotsky, 1978). The ZPD focuses on a child's readiness to learn that emphasizes upper levels of competence. With the readiness of the child, the ZPD is always changing with the increasing independent capability displayed. Vygotsky believed that what a child can perform today with assistance she will be able to perform tomorrow independently, thus preparing her for entry into a new and more demanding collaboration (Vygotsky, 1978, pp. 86-87).

Culture, Communication and APAs

The sociocultural context of individuals affects the behavior of those living in that context and also their expectations about how other individuals in the same context should or would behave (DeRosis et al., 2004). Though there are common behaviors that respond to 'universal' laws, several aspects are dependent on culture. According to Samovar and Porter (1976): "culture manifests itself both in patterns of language and thought and in forms of activity and behavior. These patterns become models for common adaptive acts and styles of expressive behaviors which enable people to live in a society within a given geographic environment at a given state of technical development". Therefore, communication style is one of the main aspects of behavior that is influenced by culture.

Cultural diversities are determined by cultural difference in norms, standards and goals, and these are reflected in the differences in communication styles - the way people reason, feel and display emotions, appear and gesture (Payr & Trappl, 2004). Some aspects of communication styles are universal and some are culturally determined. It is important to examine which difference in communication styles may be universal and which are due to cultural differences. Emotion feeling and expression, body language and gesture, verbal communication, facial expression and gaze can all be examined in relation to culture to inform APA design.

These culturally influenced differences in communication styles potentially affect human-to-computer and human-to-APA interaction. Existing embodied APAs often reflect the typically western culture of the environment in which they have been designed, by mirroring the developer's reasoning style and communication modes. According to DeRosis (2004) this may create agents that are not able to communicate with people from cultures different from their designers.

The aspects of communication that make for a believable and relatable agent include the ability to show emotions and to engage in social interactions with the user. But according to Ortony (2004) the most important aspect is consistency:

> "What does it take to make an emotional agent, a believable emotional agent? If we take a broad view of believability –one that takes us beyond trying to induce an illusion of life to the idea of generating behavior that is genuinely plausible– then we have to do more than just arrange for the coordination of, for example, language and action. Rather, the behaviors to be generated –

> and the motivational states that subserve them – have to have some consistency, for consistency across similar situations is one of the most salient aspects of human behavior. But consistency is not sufficient for an agent to be believable (Ortony, 2004, p. 189). An agent's behavior also has to be coherent. In other words, believability entails not only that emotions, motivations and actions fit together in a meaningful and intelligent way at the local level, but also that they cohere at a more global level – across different kinds of situations and over quite long time periods." (Ortony, p. 189).

According to Ortony (2004) when APA design is consistently sensitive to cultural norms, values and beliefs the agent is often perceived as more believable, relatable and trustworthy by the user. For example, in the scope of their 'Computers as Social Actors' long–term research plan, Lee and Ness (1998) investigated that effect of computer agent ethnicity in the context of human/computer interaction and computer-mediated communication. They examined the question: Does the ethnicity of a computer agent have an effect on user's attitudes and behaviors? In a study comparing a group of Caucasians with a group of subjects from an ethnic minority (Koreans), they found that ethnic similarity had significant and consistent effects on the users' attitudes and behaviors. When the ethnicity of the subject was the same as that of the computer agent with whom the subject was interacting during the experiment, the agent was perceived to be more similar, more socially attractive and more trustworthy. The agent's arguments were also perceived to be better and more convincing (Lee & Nass, 1998).

The concept of FWs has also been used to illuminate the nature of students' experiences in classroom settings. Mathematics education researchers Boaler & Greeno (2000) describe FWs as "places where agents come together to construct joint meanings and activities." In this view, a subject area classroom can form a FW with the power to shape students' senses of themselves as learners of that particular subject. In their research, Boaler & Greeno found that the FWs of many mathematics classrooms were "unusually narrow and ritualistic," utilizing "traditional pedagogies and procedural views of mathematics" (171). Within the FW of the mathematics classroom, many students refused to participate in dominant practices—such as working alone or on the rote application of formulas—that they found to be "counter to their developing identification as responsible, thinking agents" (171), and thus rejected the study of mathematics as alien and meaningless.

The concepts of inter-subjectivity, identity construction, social engagement, culture and lastly, communication, culture, and APAs were reviewed above in relation to FWs. The concept of **inter-subjectivity** explains how interacting with an animated pedagogical agent (APA) may evoke a sense of inter- subjectivity (sharing of subjective state) for some students. This intersubjective connection encourages students to respond to their animated LCs in fundamentally social ways. **Identity Construction** happens when ITSs feature APAs that allow students to design their learning companions. While, **Social Engagement** is a framework for technology-based teaching in which learning occurs when students are meaningfully engaged in activities through interaction with others and worthwhile tasks. The **Culture and Communication** framework elucidates that communication styles (appearance, gesturing, reasoning style, verbal and non-verbal communication, feel and display of emotions) is one of the main aspects of behavior that is influenced by culture. Finally, **Culture and APAs** illustrates that when APA design is consistently sensitive to cultural norms, values and beliefs FWs of cultural identity are formed and the agent is often perceived as more believable, relatable and trustworthy by the user.

Students form identities and FWs that are developed through activity/practice and are influenced by cultural and social engagement. According to Samovar and Porter, students experience culture through patterns of language and thought and in forms of activity and behavior (1976). These patterns become models for common adaptive acts and styles of expressive behaviors and help students form cultural identities and FWs. These FWs of cultural identity that are based on culturally determined aspects of communication (appearance, gesturing, reasoning style, verbal and non-verbal communication, feel and display of emotions) allow students to create FWs of learning with APAs in ITSs.

Students may form these meaningful FWs of identity and learning in ITSs with APAs when they are able to design their APAs to reflect their cultural patterns of appearance, gesturing, reasoning style, verbal and nonverbal communication and are able to collaboratively engage with them in authentic and project-based learning activities**.** Students may find that engaging with culturally consistent APAs that closely resemble themselves may promote identity construction with the APA and foster inter-subjectivity. Forming these ITS FWs may help improve motivation and learning outcomes.

This research analyzed student learning companion designs and investigated how a tutor can reach Hispanic ELL students in the context of Holland et al.'s FWs identity theory framework (1998). Based on the social and cultural identity framework of the FWs Theory by Holland et al., the researcher hypothesized that the more a learner socially engages with their APAs the more likely he or she is to form a FW (that has the power to shape the student's senses of themselves as learners of math) and be immersed in the ILE and to have a favorable or satisfactory experience.

Figured Worlds Research in Educational Settings

The FWs concept by Holland et al. and other figured worlds theorists, provides a useful theoretical framework for understanding the identity work of student digital technology practices and has been explicitly applied by researchers to educational settings. Identities develop amid FWs and in relation to them. There is a growing literature that explores the FWs of learner identity in students (e.g. Boaler and Greeno, 2000; Brown, 2017; Ellison, 2014; Hatt, 2007; Horn, 2006; Jurow , 2005; Michael et al., 2007; Robinson, 2007; Rubin, 2007; Urrieta, 2007).

FWs research in educational settings spans student digital technology practices, math education and culture and are reviewed below.

Figured Worlds and Technology

Brown (2017) drew on the theoretical framework of Holland's FWs to unpack the merging of on- and offline spaces and conceptualize identity work. Through vignettes of four young adolescents, this study demonstrated that the out-of school use of digital technologies revealed FWs of friendship, homework and soccer that transcend the traditional boundaries of the real and the virtual, revealing a connected and dynamic concept of space. Within these worlds, the young adolescents move in and out of learner and teacher roles when necessary to learn or advance their skills, and in doing this, are developing self-understandings and conveying these understandings as performances within a FW.

Additionally, Ellison (2014) used the theory of FWs to help make sense of the identity work of two young adolescents playing The Sims 2 video game. Ellison found that the digital literacy practices of two adolescents, Gerard and Jake, exemplify the ways most adolescents co-construct, negotiate, and create meaning through video games while formulating digital ontologies of self within their online spaces. Their experiences extend through the construction and production of texts while illuminating the ways in which power, race, and identifiable notions of self are developed in real and online virtualities. Ellison's research explored how Gerard and Jake infused their online fantasies with real life desires that are common with adolescents in today's societies and she states that games such as The Sims 2 allow Gerard and Jake to be active problem solvers, to create and re-create meaning while recruiting identities in a way that could be equally relevant in schools. As video games become more sophisticated and demand more attention, it is vital for schools to capitalize on these media to enhance learning.

Figured Worlds and Math

Jurow (2005) used the notion of FWs to theorize ways in which engagement in a design project based on an imaginary premise (designing a research station in Antarctica) afforded students the opportunity to use mathematics meaningfully. She describes the imaginary premise as a FW that "shaped [students'] approaches to mathematical tasks" (35). Students' participation in this FW figured strongly in how they came to be able to use "mathematics as a resource for solving problems" (35–36). Engagement with various FWs over the course of the project resulted in deeper learning and engagement (Jurow, 39). This research indicates that educators' conscious manipulation of FWs can be an asset for positioning learners positively in relation to knowledge.

Additionally, the concept of FWs has also been used to illuminate the nature of students' experiences in classroom settings. As noted above, mathematics education researchers Boaler & Greeno (2000) describe FWs as "places where agents come together to construct joint meanings and activities." In this view, a subject area *classroom* can form a FW with the power to shape students' senses of themselves as learners of that particular subject. In their research they found that the FWs of many mathematics classrooms were "unusually narrow and ritualistic," utilizing "traditional pedagogies and procedural views of mathematics" (2000). Within the FW of the mathematics classroom, many students refused to participate in dominant practices—such as working alone or the rote application of formulas—that they found to be "counter to their developing identification as responsible, thinking agents" (2000), and thus rejected the study of mathematics as alien and meaningless.

Finally, Horn (2006) expands the application of FWs from the individual classroom level to the level of *curriculum*, positing the mathematics curricula of two high schools as distinct FWs to frame her description of "turnaround" math students and their emerging "mathematical identities" in each context. In her case study, the two FWs were marked by distinct (and opposing) understandings of mathematics and the nature of mathematical learning (sequential versus conceptual; emphasis on procedures versus emphasis on solving problems). This led to the differential construction of mathematical identity in the two settings, with different outcomes for two turnaround students (students who started out performing poorly in mathematics and then improved their performance). In the school that emphasized conceptual learning, social interaction and discursive problem solving, the turnaround student maintained her positive mathematical identity throughout high school, while the student in the more traditional setting reverted to her former disaffection with mathematics after leaving the classroom of a supportive teacher.

Figured Worlds and Culture

Hatt-Echevarria (2005) examined the FW of a kindergarten classroom in which the cultural practice of "smartness" was constructed through the teacher's use of particular talk and practices that privileged Caucasian middle-class students. Hatt-Echevarria argues that within this FW, "smartness" functioned as a "tool of social privileging and silencing" (2005), penalizing many of the Black, lower income students in the class for not meeting expectations that were wholly unrelated to academic ability (such as knowing how to tie their shoes). Schooling, she argues, shapes identities in powerful ways by creating a sense of smartness (or lack thereof) that students carry with them throughout their lives. "The figured world of smartness," she writes "is located with us, not as a biological function connected to our brains, but instead as a cultural practice we use to give meaning to ourselves and others" (2005). In this way, the notion of FWs can be used to illuminate how students' identities as learners can be shaped differently amid the same learning context, and how "smartness" can be a situated phenomenon.

Additionally, Urrieta (2007) examined the ways FWs contributed to the identity formation of Chicana/o educator-activists over time, amid their multiple figured worlds of work and community. According to Urrieta, the clash of figured worlds experienced by his participants became a launch pad for the development of activist identities that empowered them to act in the world. He writes,

> "Figured worlds are thus formed through social interaction, and in them people "figure" out who they are in relation to those around them...Through participation in figured worlds people can reconceptualize who they are, or shift who they understand themselves to be, as individuals or members of collectives. Through this figuring, individuals also come to understand their ability to craft their future participation, or agency, in and across figured worlds." (Urrieta, 2007, p. 120).

Urrieta sees participation in FWs as an opportunity for participants to re-conceptualize their understanding of themselves, as well as a way to develop agency within and across the FWs they encounter (2014). Since FWs both distribute power and demonstrate, explicitly and implicitly, how power works within those worlds, Urrieta finds that the specific FWs in which his sample of educators participated greatly influenced their eventual identity formation as Chicana/o Activist Educators. In interviews and surveys, these educators identified involvement in ethnic student organizations, ethnic coursework, and cultural activities as key experiences in creating their sense of commitment and urgency in pursuing a career in activist education (2014). Urrieta argues that it is this involvement in culturally and politically active figured worlds, as well as specific life experiences such as religious and familial background, that drew the educators into the FW of Chicana/o Activist

Educator. Participation in the figured world of Chicana/o activism enabled his study participants to "re-make themselves as Chicana/o activists and later as Chicana/o activist educators". Although the scope of his study is limited, it does suggest that teacher attitudes and behaviors are influenced by their participation in FWs.

Also using FWs theory in another education study, Rubin observes teachers and students at an urban high school with a high drop-out rate to determine what "local discourses, practices, categories, and interactions" make up the FWs of learning for both students and teachers, and what effect those FWs have on students' identities as learners (2007). She describes teaching practices that focus on worksheets, textbooks, and quizzes, learning and teaching discourses that substitute chapter and page numbers for concepts, and interactions that emphasize control, compliance, and inherent and unalterable student deficits (2007). Rubin suggests that the achievement gap between Caucasian and minority students and urban and suburban schools may be the result of a FW that decontextualizes learning and uses classroom activities to control student behavior rather than foster learning.

According to Rubin, the failure of students in such a FW is actually the result of "what was available to be learned," not the inherent ability or inability of the learners. By examining this urban high school through the lens of figured worlds theory, she concludes that "everyday activities and events become part of identity production and, in this case, the reproduction of social inequalities" (2007). Thus, the impact of FWs in education can be far-reaching.

This research unpacks Holland et al.'s (1998) framework of FWs to explore how Hispanic ELL students perceive the utility of and relate to a student created avatar design. The analysis of the qualitative and quantitative findings of the study are reviewed and discussed in term of FWs.

CHAPTER 3

LEARNING IN ITSs WITH APAs

Initially, this literature review will provide an overview of the major constructs of this study, including intelligent tutoring systems (ITSs) and animated pedagogical agents (APAs). Then a summary of the roles, features and interactions of APAs is presented. Next, APAs and learner identity characteristics such as gender, ethnicity and age will be examined. After that, gender, Hispanic learners and English Language Learners (ELLs) in relation to math education will be explored

Intelligent Tutoring Systems

Intelligent Tutoring Systems are computer-based learning environments with models of instructional content that specify what to teach, and teaching strategies that specify how to teach (Wenger, 1987; Shute & Psotka, 1996). ITSs use both instructional and content models to make inferences about a student's mastery of tasks in order to adapt the content or teaching strategy and personalize instruction (Murray et al., 2003).

MathSpring ITS

MathSpring is a multimedia-based intelligent tutoring system. It provides a broad range of pedagogical support while students solve mathematics problems of the type that commonly appear on standardized test (Arroyo et al., 2004). Developed at the University of Massachusetts-Amherst and Worcester Polytechnic Institute, the MathSpring Tutor supports strategic and problem-solving abilities based on the apprenticeship model in which the master teaches skills to the apprentice. In this case, the expert is the computer program that assists the students to learn tacit processes. The program provides practice opportunities with the availability of scaffold strategies and provides metacognitive scaffolds, such as inviting students to stop and reflect on their student progress (Arroyo et al., 2013). MathSpring was originally designed in English but has recently added an additional suite of Spanish math content allowing the system can be set to English or Spanish. An ELL intervention is in the works that will allow students to switch between the English and Spanish content.

ITSs' Animated Pedagogical Agents

Today, many of ITSs feature animated pedagogical agents. APAs have artificial intelligence or an intelligent tutor system back-end that allows the designer to simulate communicative agent behavior while guiding human-agent interactions toward pedagogical goals and objectives. Since the early 2000s, empirical evidence supports the possibility that pedagogical agents facilitate deeper learning and enhance motivation to learn (Atkinson, 2002; Moreno et al., 2001).

Agent Roles

In the mid 2000s researchers started to examine the effectiveness of specific agent design features on specific learning outcomes. In 2005, Kim & Baylor investigated whether it was possible to effectively simulate human instructional roles in animated pedagogical agents. The findings of this research indicate that agents can effectively simulate instructional roles when designed with the appropriate persona and associated media features (image, voice, animation, and non-verbal communications) (Lester et al., 1997; Kim & Baylor, 2005).

Kim & Baylor's early work (2005, 2006) indicates that agents imbued with a role and persona successfully instilled a sense of human-like instructional presence and elicited social responses from college students. In 2007, Kim conducted in-depth interviews to explore college students' expectations of agent roles. The results showed that the most salient qualities that students desired were the roles of teaching (knowledgeable) and motivation (friendly and kind) (2007). Peer-like motivating agents have become popular in the form of pedagogical companions or virtual peers. Motivating peer-like agents have been emphasized for students who are learning challenging topics (Arroyo et al., 2011, 2013; Kim & Baylor, 2006; Kim et al., 2007).

It is thought that APAs can influence a social interaction schema that can positively influence student motivation (Atkinson 2002; Domagk 2010; Moreno et al. 2001; Moreno et al. 2010). According to Johnson et al. (2000), "APAs increase the bandwidth of communication between students and computers and they increase the computer's ability to engage and motivate students" (p2). Johnson et al. (2000) found that these two features ultimately improve learning outcomes and experiences.

More importantly, peer-like agents effectively served as coping models for females who learned STEM topics, helping enhance positive affect and motivation

(Kim & Baylor, 2007; Kim & Lim, 2013).

Agent Features

Research has shown when carefully coordinated, media features used to define agent roles may increase an agent's believability and naturalness. Several studies have investigated to what degree each of the media features could contribute to improved learning and motivation. For example, if the agent's appearance and voice were perceived as likable, this positively contributed to motivation and transfer of learning (Domagk, 2010; Mayer, 2005). Some argue that agent voice is the most important feature in the effectiveness of agent (Atkinson et al., 2005; Bente et al., 2008); however, other research indicates that the visual presence of an agent is significantly better than voice alone (Rosenberg-Kima et al., 2007). Further, other research reveals that the agent's nonverbal communication (deictic gestures and emotional expression) differentially influence the learning of procedural knowledge as compared to attitudinal information (Baylor & Kim, 2009). Overall, by carefully designing the agent's appearance, voice, nonverbal communication, and messaging, it has been shown that the agent can differentially impact specific learning and motivational outcomes (Baylor, 2011).

Agent Interactions

More recently, pedagogical agent research has expanded its scope from the focus on agents providing instructional expert guidance to a broader interest in agents' social and affective capabilities to support learners (Veletsianos & Russell, 2014).

Initially, the focus was on building intelligent agent-based systems to guide the learning processes, with the expectation of some motivational benefit through visual presence recently with the involvement of researchers across diverse disciplines, including social psychology, the research issues have expanded to include interest in the social and relational aspect of agent and learner interactions (Kim & Baylor, 2015).

A variety of recent empirical evidence has been collected that embodies the social nature of pedagogical agents. Wang et al. (2008) reports that an agent who presented polite feedback increased the learning outcomes of college students more than an agent who presented direct feedback. Similarly, Haake & Gulz (2009) found that female students chose an agent that focused on developing social relationship during a learning task over an agent that was strictly task-oriented as their learning companion. Additionally, human relation attributes have been consistently applied to agent-learner relations. For instance, high school students chose to work with a peer-like agent over a teacher-like agent (Kim et al., 2007) and also preferred to work with an agent with the same ethnicity more than with a different ethnicity (Kim & Wei, 2011; Moreno & Flowerday, 2006; Plant et al., 2009). Furthermore, researchers Rosenberg-Kima et al., (2008) reported that female students chose cool and younger agents as their ideal social model agents; however, agents with expertise (although older and uncool) were as effective as the young and cool agents.

Agents and Learner Characteristics

The examination of agent impact in terms of learner characteristics such as gender, ethnicity and age are noteworthy due to the vast differential expectations between diverse groups of learners.

Gender

Research indicates that females across age groups are more favorable toward agent- based interactive learning environments than are males (Arroyo et al., 2003, 2013; Kim and Baylor, 2006; Kim et al., 2006; Kim et al., 2007). Kim et al, (2006) agent gender impact study indicated that the female agents were favored by the high school girls and had positive impacts on improving the girls' math self-efficacy and attitudes. Additionally, Arroyo et al, (2013) found that gender differences were seen in the students' style of use of the system, motivational goals, affective needs and cognitive/affective benefits, as well as the impact of affective interventions involving pedagogical agents.

Arroyo et al., (2011) reported a higher benefit of learning companions for female students during an evaluation of pedagogical agents in real school settings, with about 100 students from a public high school in Massachusetts. One of their main findings was that gender has a key impact within the context of tutoring systems for mathematics. In general, the effects were stronger for females than for males. Females' confidence was improved with learning companions but this was not the case for the males. Girls perceived the learning experience significantly better when learning companions were present, while the opposite was true for males (Arroyo, 2011). Female students also had more productive behaviors in the tutor when the companions were present than when they were absent: they spent more time than males on problems where help was seen. They also had less unproductive behaviors: they "quick-guessed" and clicked fast through hints less when characters were present. At the same time, a significant interaction effect for learning companions (LC) presence and gender revealed that the opposite is true for males: they have less productive behaviors when LCs are absent.

Researcher, Kizilkaya & Askar (2008) also found that the presence of pedagogical agents in multimedia module provides a more stimulating effect on girls. Female students who use the tutorial with a pedagogical agent performed better compared to the boys (2008). Thus, instructional designers need to analyze the characteristics of the user before starting the design process.

Also, over the years Arroyo et al., (2011) have found empirical evidence that females are more "diligent" when using tutoring systems, showing behaviors that are more conducive to learning than those of male students (e.g., spending time on hints or accepting help when offered). Overall, they find that females report better general attitudes while learning with tutoring systems (Arroyo & Woolf, 2005), even without the character. These results suggest that females and males may need to be considered separately, as what works for females does not necessarily work for males.

Ethnicity & Age

According to Moreno & Flowerday, college-aged students of color are more positive to an agent that is culturally similar to themselves than to a culturally dissimilar agent (2006). Interestingly, Kim & Lim (2013) also report that middle grade females and ethnic minorities expressed their comfort in learning from an agent, improved their self-efficacy in learning algebraic concepts, demonstrated positive attitudes, and increased learning significantly after working with the agent, as compared to the behavior of Caucasian males.

Researchers designed the image of pedagogical agents with different ethnicities (Caucasian or African-American). The results (Baylor, 2005) showed that African-American learners were significantly more likely to choose an agent with the same ethnicity and also have significantly more positive attitude toward the chosen agent after learning from it. It was found that African-American agents lead to increased self-regulation compared to Caucasian agents. In addition, ethnicity has an impact on student learning. Post hoc t-tests showed significant differences between African-American experts ($M = 2.61$, $SD = .75$) and the Caucasian experts ($M = 2.13$, $SD = .84$, $p < .01$), which indicates that African-American agents are more effective in their role as an expert than Caucasian agents. Apart from that, students reported significantly more facilitation of learning (e.g., focus on relevant information, help in concentration) from the African-American Expert agents (Baylor, 2005) and African-American Experts (Baylor & Kim, 2004). Baylor (2005) also reported that the

African-American Motivator agents were rated as significantly more enjoyable, enthusiastic, motivational than the Caucasian Motivator agents (d=.40).

Additionally, a meta-analysis by Schroeder et al. (2013) indicates that agent presence seemed to have a more positive influence on K-12 students than on college-level students.

Cis-gender and Math Education

The scope of this section is limited to cis-gender (someone who exclusively identities with their sex assigned at birth) and math education, which is a limitation of this research but also more importantly a limitation in today's educational research and an injustice to students who do not identify or exclusively identify with their sex assigned at birth. Further research is needed to look at variations of gender (transgender, non-gender, genderqueer/non-binary or gender-fluid) and math education.

Research suggests that girls and boys have different approaches to problem solving (Fennema et al., 1998) and that they should be taught differently (Sax, 2005). Moreover, boys' and girls' learning styles are different, with girls tending to ask for help and boys using the teacher only as a last resort. Some of that research has indicated genders respond to different motivational techniques: boys respond better to time constrained tasks and pressure situations than do girls (Arroyo et al., 2011).

Also, in addition to fighting the societal stereotype messages that females are not good at math, studies have shown that girls have lower levels of confidence in their math abilities than boys (Else-Quest et al., 2010; Else-Quest et al., 2013; Ganley, 2016; Hyde et al., 2008). Additionally, research on gender differences and learning suggest that female students may have higher affective needs in certain disciplines; for example, in early adolescence gender and ethnic differences exist in mathematics self-concept (a student's belief about their ability to learn mathematics) and mathematics utility (the student's belief that mathematics is valuable to learn) (Eccles et al., 1993; Catsambis, 2005).

Specifically, girls have less liking for math, more negative emotions and more self-derogating attributions about their math performance (Eccles et al., 1993). Eccles (1993) accessed this by measuring how interesting/fun each activity is, how important being good at the activity is to the child, and how useful the child thinks the activity. Similarly, Frenzel et al., (2007) found that girls reported significantly less enjoyment and pride than boys, but more anxiety, hopelessness and shame. Findings suggested that the female emotional pattern was due to the girls' low competence beliefs and domain value of mathematics, combined with their high subjective values of achievement in mathematics (2007).

This poor affective relationship to the subject is likely one reason why females do not choose advanced math classes and later science careers in college (Catsambis, 2005), as compared to males whom maintain a more positive relationship to math throughout. Thus, helping girls in particular to foster a positive affective relationship to mathematics is highly relevant (Arroyo et al., 2011).

Research suggests that using math ITSs with APAs with female students may be a way to nurture a positive affective relationship to mathematics. Math ITSs that allow female students to create peer-like learning companions may support students in creating their own figured world of collaborative learning with their APA which may result in a more positive attitude towards math. When students have a hand in creating their figured world, they might identify more with the activity and that identification may lead to deeper engagement and more learning.

ELLs and Math Education

According to the National Center for Education Statistics (NCES), the percentage of public-school students in the U.S. who were English Language Learners (ELLs) increased from 8.1 percent, or 3.8 million students in the Fall of 2000 to 9.6 percent, or 4.9 million students in the Fall of 2016 (National Center for Education Statistics, 2019). NCES has also reported that in the Fall of 2016, the percentage of public-school students who were ELLs was 10.0 percent or more in nine states. Reflecting the national change, the percentage of public-school students who were ELLs was higher in Fall 2016 than in Fall 2000 for all but seven states and the District of Columbia. More recently, the percentage of public-school students who were ELLs was higher in Fall 2016 than in Fall 2010 in 35 states and the District of Columbia, with the largest increase occurring in Massachusetts (3.3

percentage points). The state with the most ELL students is California — which has 29 percent of all ELLs nationwide (2019).

It is important to design effective accommodations for math students whose primary language is not English. Unfortunately, scarce research exits on ELLs and ITSs and research is even scarcer when it comes to understanding effective ITS pedagogical design for ELLs.

Abedi et al. (2000) found that different students learned different amounts based on different standard classroom accommodations for ELLs middle and High School students across three levels of math. Some accommodations might help certain student subgroups, and not others. Specifically, the accommodation of providing extra time resulted in slightly higher math scores for most students but not for all subgroups. For example, students enrolled in 8th grade general math classes, as compared with those students enrolled in pre-algebra and algebra classes, did not score higher with extra time. The accommodation providing an English glossary with definitions or paraphrases of potentially difficult mathematical words or phrases had a negative impact on the performance of certain student groups (Abedi et al., 2000).

Abedi et al. (2000) also found that the provision of an English glossary plus time helped all students and resulted in higher scores for all student subgroups. More importantly, they found that the only accommodation that narrowed the gap between the ELLs subgroup and the other students was a linguistic modification of the test items (2000). This suggests that this accommodation warrants further investigation.

Hispanic ELLs and Math Education

Spanish is the primary language for most ELL students. Of the top five most common foreign languages spoken among ELLs, Spanish ranks number one by a large margin. ELL students speak over 400 languages but 80% of them speak Spanish in the home (U.S. Department of Education, 2007). The NCES reports that in the Fall of 2016, there were about 3.82 million Hispanic ELL public school students, constituting over three-quarters (77.2 percent) of ELL student enrollment overall. Asian students were the next largest racial/ethnic group among ELLs, with 521,300 students (10.5 percent of ELL students). Mexicans are by far the most predominant Hispanic group in the United States, representing 59 percent of the Hispanic population. Next in size are Puerto Ricans (10 percent), Central Americans (including Dominicans; 7 percent), South Americans (4 percent), and Cubans (3.5 percent) (Guzman, 2001; Ramirez, 2004).

Hispanic ELL students were chosen for this study because they are one of the most vulnerable populations of math learners in the U.S. Based on recent cross-sectional national studies researchers report that that the educational outcomes of Hispanic students in U.S. schools lag, on average, well behind those of non-Hispanic students (Reardon et al., 2009). Reardon et al., report that Hispanic students enter kindergarten with much lower average math skills, compared to non-Hispanic

Caucasian students. They found that average Hispanic and Black students begin kindergarten with math scores three quarters of a standard deviation lower than those of Caucasian students and with reading scores a half standard deviation lower than those of Caucasian students (Reardon et al.). According to Reardon et al., researchers have also found that high school completion rates for Hispanic students are substantially lower than those for either Caucasian or Black students. Likewise, Hispanic students are less likely than Caucasian students to attend and graduate from college and are more likely to be enrolled in 2-year colleges than in 4-year colleges (Reardon et al.). Fry (2004) cites student preparedness and college selection as the main reasons that Hispanic students are less likely than Caucasian students to attend and graduate from college. Fry reports that about half of Hispanic students are not minimally prepared academically to enroll in college and those who are prepared attend less selective colleges and have lower graduation rates than Caucasian students (2004).

Overall ELL Achievement

As a whole, ELLs still lag behind in terms of academic achievement. According to the NCES only 63 percent of ELLs graduate from high school, compared with the overall national rate of 82 percent. In New York State, for example, the overall high school graduation rate is about 78 percent. But for ELLs, it's 37 percent (NCES, 2016).

One reason often put forth by researchers to explain ELLs' academic underachievement relates to content-area teachers' inadequate preparation to teach culturally and linguistically diverse learners (Santoro, 2007). ELLs are often concentrated in low-performing schools with untrained or poorly trained teachers. These schools with high over-all proportions of ELL students tend to have higher incidences of poverty and more diverse, but often less qualified and experienced teachers. The shortage of teachers who can work with this population is a big problem in a growing number of states. In 2016, thirty-two states reported not having enough English as a second language (ESL) trained teachers for ELL students (NCES, 2016).

In fact, in national survey conducted by National Clearinghouse for English Language Acquisition (NCELA) revealed that less than one sixth of colleges offering pre-service teacher preparation included training for working with ELLs. In that survey, 80% of the teachers stated that they had participated in professional development related to their state or district curriculum, but only 26% had received professional development workshops that focused on working with ELLs (National Clearinghouse for English Language Acquisition, 2008). Furthermore, approximately 57% of the teachers reported that they needed more training to provide effective instruction for ELLs. There is a critical need for more ELL programs and a need to train and recruit more ELL teachers to serve this rapidly growing student population.

ELL Achievement Gap in Mathematics

Achievement gaps between ELLs and non-ELL students are deeply rooted, pervasive, complex, and challenging. As a group, ELLs face some of the most pronounced achievement gaps of any student groups. One source of information on the mathematics achievement gap comes from The National Assessment of Education Progress (NAEP). The NAEP mathematics assessment measures student performance across grade levels in the five areas of algebra; geometry; measurement; number properties and operations; and data analysis, statistics, and probability.

According to NAEP, among fourth grade students who were identified as ELL, the national average mathematics score on this measure has remained between 217 and 219 – slightly above a "basic" level – for every year between 2007 and 2015. During this time, non-ELL students' scores have remained between 242 and 244, which is slightly below a "proficient" level. For reference, in fourth grade a score at or above 214 represents a basic understanding (i.e., mastery of some of the knowledge and skills expected for that grade), while a score at or above 249 represents proficient understanding (i.e., demonstrated mastery of all the knowledge and skills expected for the grade). This performance gap of approximately 25 points has persisted over the past 8 years (U.S. Department of Education, 2015).

Among eighth graders completing the NAEP mathematics measure, ELL students have averaged between 243 and 246 during this period, while non-ELL students have averaged between 283 and 287. This represents a consistent difference of about 40 points. For eighth graders, a score at or above 262 is considered a basic understanding, while at or above a 299 is considered proficient. In other words, in 2015, the average ELL student in fourth grade demonstrated a basic understanding of the NAEP mathematics content areas, while the average ELL student in eighth grade was categorized as having less than a basic understanding (U.S. Department of Education, 2015c). According to NCES (2015), ELL students graduate from high school "at the lowest rate of all student subgroups."

On the state level, in Massachusetts, while 40% of all 8th graders score at proficient and above in the state mathematics assessment, only 13% of ELL 8th graders score at this level (Rennie Center for Education Research & Policy, 2007).

Furthermore, according to a 2019 NAEP report, there was no significant change in National student group scores and score gaps, in the 24-point Caucasian – Hispanic score gap in 2019 compared to either the 24-point score difference in 2017 or the 24-point difference in 1990 for 8th grade math students (NAEP, 2019).

ELL Students and Math Performance

Student, culture and classroom factors may influence ELL students and their math performance.

Student Factors: Some ELL student factors that influence math performance include English language proficiency, primary language proficiency and socioeconomic status.

Language and literacy skills are critical to building knowledge in mathematics, especially in the language-heavy mathematics instruction common in American schools (Dale & Cuevas, 1992; Jarret, 1999). We may tend to think of mathematics as a subject that does not require a strong command of language. In reality, however, mathematical reasoning and problem solving are closely linked to language and rely upon a firm understanding of basic math vocabulary (Dale & Cuevas, 1992; Jarret, 1999). Solving word problems, following instructions, understanding and using mathematical vocabulary correctly all require language proficiency.

Written word problems present a unique challenge to ELL students and teachers alike. In the article, "Reading and Understanding Written Math Problems", Brenda Krick-Morales writes, "Word problems in mathematics often pose a challenge because they require that students read and comprehend the text of the problem, identify the question that needs to be answered, and finally create and solve a numerical equation. For many ELLs who have had formal education in their home countries their struggles begin when they encounter word problems in a second language that they have not yet mastered" (Bernardo, 2005).

The literature underscores the importance of bilingual instruction that integrates content and academic language development in classroom instruction (August et al., 2005; Calderon, 2007; Garrison et al., 2006; Snow, 2007). Linguists and cognitive specialists recognize that language enables students to bring order and meaning into their classroom experiences and should be practiced by second-language students "not only as a communicative tool but also as a cognitive tool for interacting with the teacher, with one another, and with content knowledge itself" (Lyster, 2007, p. 22).

Socioeconomic status is another student factor that influences math achievement. According to Carnoy & Garcia (2017), gaps between higher- and lower-income students persist and the proportion of low-income students in U.S. schools has increased rapidly, as has the share of minority students in the student population. In their, "Five key trends in U.S. student performance", report Carnoy & Garcia (2017) find that despite some achievement gap gains, students are still harmed by attending high-poverty schools. Attending a high-poverty school lowers math and reading achievement for students in all racial and ethnic groups, and the chances of ending up in such a school are largely determined by a student's race and ethnicity and social class. Black and Hispanic students, even if they are not poor, are much more likely than Caucasian or Asian students to be in high-poverty schools. They are also much more likely to attend a school in which Black and Hispanics make up more than 75 percent of the student body. Attending such racially segregated schools has a much larger negative effect on Black, Hispanic, and Asian students' achievement than it does on Caucasian students (Carnoy & Garcia).

Cultural Factors Additionally, student factors that are influenced by culture include learning styles, math symbols and concepts and instructional methods. ELLs are from diverse cultures and their cultures influence student learning styles, math symbols and concepts in addition to instructional methods. Learning styles differ greatly in Eastern countries. For example, in many Asian countries, rote memorization and self-study form the basis of schooling and learning. Thus, students may have little or no experience working in cooperative groups, let alone collaborating on how to solve problems.

It is also important to note that some symbols serve different functions in different cultures. For example, the use of the comma and decimal point varies from culture to culture. Students from South America, Asia, and many European countries use the comma in expressing currency values, whereas Americans use a period. Some mathematical concepts may also differ in various countries, thus making it challenging for ELL students to re-learn math concepts. One example is measurement. Most countries around the world such as China, India, and France, use the metric systems in weights and measures; only the United States, Liberia and Myanmar do not use the metric system. Image the mistake a student might make in assessing height in solving a math problem. The response given may be 1.82 meters, while we in the United States are looking for 6 feet tall. These varying concepts in culture may impede ELL students understanding and affect their learning math.

Finally, culture also influences instructional methods that may be geared to promoting rote memorization learning styles as opposed to cooperative learning.

Classroom Factors Furthermore, classroom factors that may also influence ELL math performance include instructional formats (teacher directed whole class, teacher directed small group, teacher directed individual activities, and student-selected activities) and teacher strategies (visual representation, computer-based work, collaborative learning, bilingual instruction).

Hispanic ELL Students' Math Performance.

Factors that are specific to Hispanic ELL students that may impede their math achievement include language, culture and socioeconomical obstacles.

A 2006 NEA study, "Report on the Status of Hispanics in Education: Overcoming a History of Neglect", reveals challenges to Hispanic students and how language, cultural, and socioeconomic obstacles impede their academic achievement. According to NEA, Hispanics have poverty rates that are two to nearly three times higher than Caucasians; and 40 percent of their population is foreign born (2006).

Language proficiency has been found to be associated with ELL performance in mathematics. It is important to understand that language is not only a tool for communicating, but also a tool for thinking. Every mathematics teacher is a language teacher- particularly the academic language used to formulate and communicate mathematics learning (Lager, 2006). According to Lager (2006), in order to be successful in mathematics, students must have both everyday language skills, as well as specialized mathematical language skills. Unfortunately, many ELL students lag behind in these areas, and therefore cannot fully access the content of their mathematics lessons (Lager, 2006). Halle et al. (2012), examined the relation between literacy and mathematics performance using a longitudinal educational data set. These authors classified the dataset into 2,670 ELL students and 19,890 native English-speaking students based on parents' reported language spoken at home (i.e., students whose parents reported a language other than English spoken primarily at home were categorized as ELL). These authors found that ELL students who were proficient in oral English when they entered kindergarten did not demonstrate an initial achievement gap in math as compared with their native English-speaking peers, and had comparable growth rates in both reading and math until eighth grade. The ELL students who were not proficient in oral English by the spring of first grade, however, did have an initial performance gap in both reading and math that persisted through eighth grade. These results were obtained after controlling for age at school entry, disability status, parent education, and family income. It is important to note, however, that these authors defined ELL students as those who spoke a language other than English at home, and therefore some students proficient in English were categorized as ELL for the purposes of this study (Halle et al., 2012).

There are also **<u>cultural factors</u>** that are specific to Hispanic ELL students that may impede their math achievement, including mathematical notations and symbols and mathematical concepts and procedures that are different from the U.S. For example, as far as **notations and symbols** in many Latin American countries, the crosshatch is drawn thru the 7 to distinguish it from the numeral 1. The numeral 8 is often drawn from the bottom up. The numeral 4 is also sometimes drawn from the bottom up. Students may confuse 4s and the 9s. The numeral 9 may resemble a lowercase "g", particularly when written by Cuban students.

As far as reading numbers in the U.S. the number 23,467,891,705 is read as - 23billion, 467million, 891thousand, 705. In Latin American countries and in U.K. it is read as: 23 thousand million, 467million, 891thousand, 705. In Spanish as: 23mil 467milliones, 891mil, 705.

In the U.S. numbers are separated by groups of 3 (otherwise known as periods) and separated by commas. In some Latin American countries, the point is used to separate such groups - U.S. - 9,435,671 and Latin American Countries - 9.435.671). In some Latin American countries, a space is also used to separate groups of 3 and/or periods. This is especially true in Argentina. As per the Secretaría de Educación Pública of Mexico 1993, millions are separated by an apostrophe, and commas separate multiples of thousands. The semicolon is also used in Mexico to separate the millions period from the thousands period. In Mexico negative numbers may be written either of two ways 1) As they are written in the U.S. with a preceding negative sign or 2) With a bar over the number. The latter format may be confused as repeating decimal fraction. In the U.S. a repeating decimal is written with a bar over the digit that is repeating and/or the repeating digit(s) are shown followed by three dots. Some books from Mexico indicate a repeating decimal with an arc rather than a line above the number. The POINT located at the bottom is used to define a decimal fraction. In the U.S. the point is used to separate the whole number from the fraction. In some Latin American countries, the comma is used to separate the whole number from the fraction.

In the U.S. the POINT is located in the center between 2 numbers and indicates multiplication. In Mexico, a bolder or larger raised point is used to represent multiplication. In some countries, the point located on the lower part between two numbers also indicates the product of the two number. The Latin American countries have one additional division symbol than the U. S. It is the colon (:) Hence, the division of 26 by 2 can be written as 26÷2, 26/2, 2 26 or 26:2.

Additionally, many Latin American countries place the angle symbol (indicating more or less than) above a number and is also much narrower than the U. S. symbol. Furthermore, in many Latin American countries, the month and date are reversed as compared to the format used in the U. S.

Miss-matched mathematical **concepts and procedures** may also impede learning for Hispanic ELL math students. There are many differences between the U.S. and Latin American Countries. In the U.S. prime factors are generally found using factor trees. Often students have difficulty finding all factors since they are spread out all over the tree. In many Latin American countries, especially in Mexico, a vertical line is used to find the same process.

In the U.S. the most common procedure to divide fractions is to invert the second fraction and then multiply. In Mexico, students cross-multiply. The numerator of the first fraction is multiplied by the denominator of the 2nd fraction. That product is the numerator of the answer. Likewise, the denominator of the first fraction is multiplied by the numerator of the 2nd fraction and the product is the denominator of the answer. This is equivalent of multiplying the 1st fraction by the inverse of the 2nd fraction.

In the U.S. the prime factorization method is one of the methods used to determine the Least Common Multiple (LCM). Students find the product by using each prime the greatest number of times it appears in the factored form of any one number. To obtain common denominators, Mexican textbooks show both denominators decomposed into primes. The LCM is found by multiplying all the common prime factors and the prime factors that appear in at least one of the two denominators. Another way that the LCM is shown in the U.S. is using Venn diagrams.

Additionally, many students come into the U.S. schools using algorithms learned in their country of origin. For example, students in many Latin American countries are taught subtraction using the equal additions method. According to this method the addition of equal numbers to the subtrahend and minuend does not affect the difference.

Furthermore, **socioeconomic** obstacles relating to poverty are specific to Hispanic ELL students and may impede their mathematics achievement. The NEA's (2006), "Report on the Status of Hispanics in Education: Overcoming a History of Neglect", finds that Hispanic students often face unique challenges in student achievement, influenced by the fact that Hispanics have poverty rates that are two to nearly three times higher than Caucasians. Although there are exceptions, according to the NEA, students from poor family backgrounds tend to do poorly in school. They usually attend schools with inferior resources, lack access to health care, and often live in families that can't advocate for them. The 2000 census reported that the poverty rate for Hispanics was 22.6 percent and 28.6 percent in 2004. The research cited above has provided preliminary information on which ELL students may be at an increased risk of experiencing mathematics difficulties.

Supporting Hispanic ELL Students' Math Learning with ITSs

Research supports the use of learning environments that feature multimodal mathematical communication that includes speaking, writing, diagramming, gesturing, etc., to reinforce the learning of mathematical representation, language, and the norms of mathematical communication (Chval & Khisty, 2001; Goldenberg, 1991; Khisty & Chval, 2002; Moschkovich, 2002).

ITSs may support ELL math performance because they may provide multimodal forms of communication and assist teachers in providing individualized and effective instruction while providing culturally relevant or real-world examples. ITSs are able to present math problems visually and verbally, allow for self-directed exploration and deliver scaffolded mastery-based learning while meeting each student's learning needs, regardless of language or achievement level. Additionally, ITSs provides data for learners to monitor their own progress, real-time feedback and opportunities for bilingual instruction. Furthermore, ITS APAs provide opportunities for cooperative and collaborative learning.

Research suggests that using math ITSs with APAs may be a way to foster a positive affective relationship to mathematics. ITSs that allow students to create peer-like learning companions may support students in creating their own figured world of collaborative learning with their APA which may result in improved confidence and in a more positive attitude towards math for females. When students have a hand in creating their figured world by designing their APA with culturally and socially familiar features, it may help them identify more with the activity and that identification may lead to deeper engagement and improved motivation and learning. Research has found that when APA design is ethnically similar to the student and consistently sensitive to cultural norms, values and beliefs the agent is often perceived as more socially attractive, believable, relatable and trustworthy by the student and had significant positive and consistent effects on the students' attitudes and behaviors (Baylor, 2011; Baylor & Kim, 2009; Domagk, 2010; Mayer, 2005).

Summary

ITS pedagogical peer-like motivating agents have become popular in the form of learning companions or virtual peers and motivating peer-like agents have been emphasized for students who are learning math topics (Arroyo et al., 2011, 2013; Kim & Baylor, 2006; Kim et al., 2007). Moreover, researchers report that peer-like agents effectively served as coping models for females who learned STEM topics, helping enhance positive student affect and motivation (Kim & Baylor, 2007; Kim & Lim, 2013).

Also, it has been shown that by carefully designing the agent's appearance, voice, nonverbal communication, and messaging the agent can differentially impact specific learning and motivational outcomes (Baylor, 2011). A variety of recent empirical evidence has demonstrated that social pedagogical agents contribute to improved learning and motivation (Baylor, 2009; Baylor, 2011; Baylor et al., 2004; Domagk, 2010; Heidig & Clarebout, 2011; van der Meij et al., 2015).

Furthermore, research suggest that girls and boys may need to be considered separately, since what works for some girls does not necessarily work for some boys. Arroyo et al., (2011) report that females' confidence was improved with learning companions but it was not the case for the males. Girls perceived the learning experience significantly better when learning companions were present, while the opposite was true for males, who reported better perceptions of learning when the learning companions were absent (2011). This gender effect may suggest that the inclusion of APAs in ITSs may be a disadvantage for male students.

ELL students represent a rapidly growing and diverse population and Spanish is the primary language for most ELL students. As a whole, ELLs lag behind in terms of academic achievement. Specifically, the National Assessment of Education Progress (NAEP) reported that in 2015 the average ELL student in eighth grade was categorized as having less than a basic understanding of the NAEP mathematics content areas (U.S. Department of Education, 2015).

Hispanic ELL students are specifically one of the most vulnerable populations of math learners in the U.S. Recent studies indicate that the educational outcomes of Hispanic students in U.S. schools lag, on average, well behind those of non-Hispanic (Reardon et al., 2009). Language, culture and socioeconomical factors are obstacles that impede math achievement of Hispanic ELL students. Research is scarce when it comes to effective accommodations for ELL math learners and the kinds of traditional and ITS pedagogical accommodations that are or are not useful. Due to this gap in knowledgde, research is needed to understand how to design effective ITS pedagogical agent accommodations for ELLs studying mathematics.

The previous identity chapter explored Holland et al.'s (1998) Figured World's identity theory that is socially and culturally constructed through activity. FWS are spaces where people 'figure' who they are through the roles, activities, and relationships that are performed in these worlds.

Students may form these meaningful FWs of learning in ITSs with APAs when they are able to design their APAs to reflect their cultural patterns of appearance, gesturing, reasoning style, verbal and nonverbal communication and are able to collaboratively engage with them in authentic and project-based learning activities. Students may find that engaging with culturally consistent APAs that closely resemble themselves may promote identity construction with the APA and foster inter-subjectivity. Forming these ITS FWs may help improve attitude, motivation, confidence, and learning outcomes.

This research evaluated the impact of the MathSpring APA design and analyzed student created LC designs to investigate how ITSs with APAs may support improved math learning for Hispanic ELL students in the context of Holland et al.'s FWs identity theory framework (1998) and examines the following research questions.

Research Questions

The overall focus of this research is on how learning in ITSs with APAs may support ELL/Hispanic students' math performance. The specific focus of this research is on how to improve the MathSpring pedagogical agent design and interactions to potentially have a positive impact on affect and learning outcomes for all students in our diverse society, especially ELL math students. Research participants designed learning companion avatars and reported on how and why they created the learning companions the way they did. In that vein, the following questions were asked to evaluate the impact of the MathSpring APA design and the student created LC designs.

MathSpring APA design RQs:

- RQ#1: How do Hispanic ELL students describe the design of how the MathSpring pedagogical agent looks, sounds and what they say?
- RQ#2: How do Hispanic ELL students perceive the utility of the pedagogical agent and learning math in MathSpring? Do students find the MS pedagogical agent useful?
- RQ#3: What aspects of the pedagogical agent do Hispanic ELL students find helpful and in what ways?

Student created LC designs RQs:

- RQ#4: Are the characteristics of the Hispanic ELL student designed learning companions similar or different to the student?
- RQ#5: How do Hispanic ELL students describe their student created learning companion designs and how do they explain their design choices.

CHAPTER 4

METHODOLOGY

This section describes the methodology, including the overall research design, informed consent and the case and main studies are presented. For each study, the specific study design, participants and materials are described. Then, the procedure is explained in detail, mapping the data that was collected to the research questions. Finally, the analyses for both studies is presented.

Overall Design

This research was conducted with an established mathematics tutor called MathSpring that includes a student model that assesses individual student knowledge and effort exerted (Arroyo, Mehranian & Woolf, 2010). MathSpring also adapts the problem choice to a student's perceived learning needs and provides help using multimedia; it incorporates audio, animated hints, tutorial videos, and example problems. Additionally, it provides a learning companion (LC) that delivers affective messages to support student interaction with the system. The LCs (see Figure 1), Jane and Jake, suggest to students that their effort contributes to success, and that making mistakes only means more effort is needed. Companions use about 20 different messages focused on effort and growth mindset (Table 1). Jane is the most complete and the main MathSpring LC and she is used for this research.

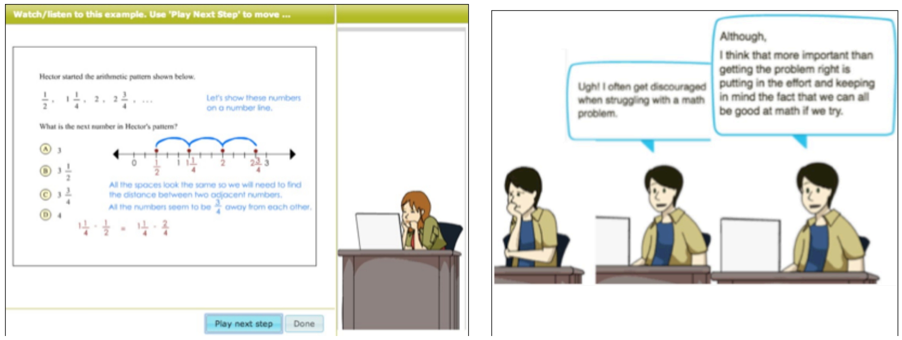


Figure 1: The learning companion (LC), Jane, shows high interest while the student views an example problem with solution steps (left). The LC, Jake, provides a growth mindset message, encouraging the student to put in effort to become good at math (right).

Table 1: Examples Messages Spoken by MS LC

Condition	Message
Empathy	"Don't you sometimes get frustrated trying to solve math problem? I do. But guess what. Keep in mind that when you are struggling with a new idea or skill you are learning something and getting smarter."
Growth Mindset	"Hey, congratulations! Your effort paid off, you got it right!" "Did you know that when we practice to learn new math skills our brain grows and gets stronger?" "Let's click on help, and I am sure we will learn something."
Success/Failure	"Very good, we got another one right!" "Hmm. Wrong. Shall we work it out on paper?"

The companion design study uses an exploratory process with quantitative measures along with qualitative semi-structured interviews and open-ended survey questions in order to gain more knowledge about improving intelligent tutoring system (ITS) companion design and interactions. This will potentially provide a positive influence on all math learners, especially Hispanic, English language learners.

This research contains two studies, a small case study to inform the main study and the main study that focused on student design of their own learning companions. Students participated in similar learning companion design activities in both studies. One-on-one interviews about the MathSpring animated pedagogical agent (APA) and the student created LC designs during the case study were used to help inform the survey for the main study.

Classes with numerous Hispanic learners, many of who were English language learner (ELL) students were used for both studies. The case study's participants were from the Northeast and primarily identify as Puerto Rican. The main study's participants were from the West coast and primarily identify as Mexican Americans.

This research used a mixed-method approach featuring interviews, visual artifacts, and surveys. The case study consisted of a two-day MathSpring workshop and the main study of a two-day MathSpring classroom trial along with a second two-day MathSpring workshop. A mixed-method design was employed because it permits deeper explanations of the results of the quantitative analysis through the qualitative results. According to Patton (1990), "qualitative data can put flesh on the bones of quantitative results" (p.132). The degree to which participants identify with the MathSpring APA and their LC designs was determined by quantitative methods. Then, the qualitative interview and survey data was thematically analyzed and used to triangulate and shed light on the quantitative survey data. Finally, artifact analysis of the student learning companion designs created with My Blue Robot was used to triangulate and shed light on the interview and survey data. My

Blue Robot is a simple avatar creation program that allows users to change many aspects of the avatars face, see Figure 2. The application provides endless opportunities for designing avatars. The My Blue Robot application allows users to choose from face shapes, color features, and mouth, nose and ear features. Users also choose from eyes shape and color features for defining the iris, eyebrows and glasses. Additionally, users choose from hair, clothes and background shape and color features. All elements of the design are moveable via the arrows and can be resized via the positive or negative magnifying-glass icon buttons. The application is found at: https://mybluerobot.com/create-your-own-avatar/.

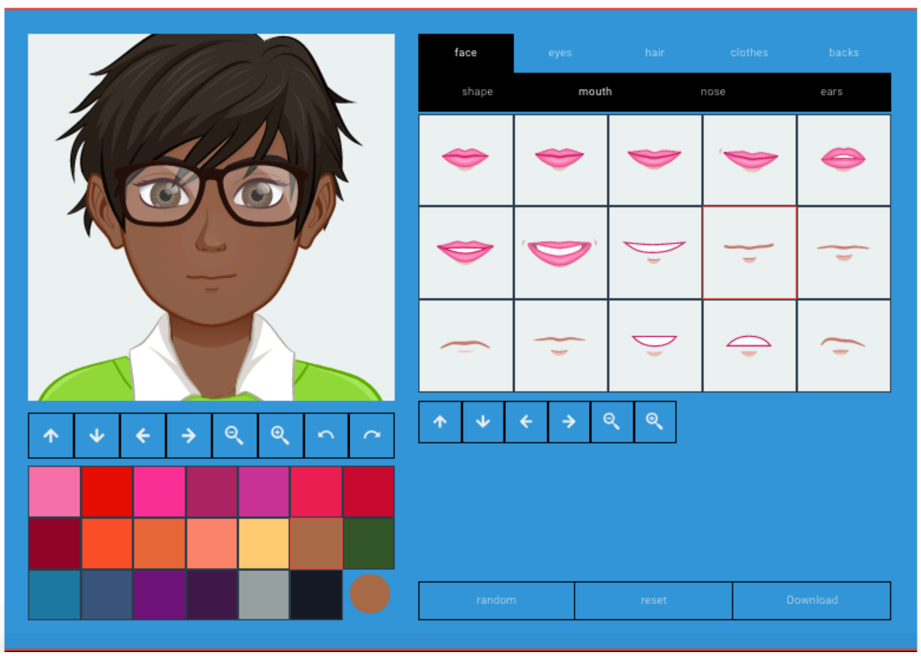


Figure 2: My Blue Robot Avatar Design Application.

Artifact analysis was used to investigate the student learning companion designs created with My Blue Robot. Students were asked about and referred to their learning companion designs during their interviews. One advantage of including visual methods such as image creation with interviews is that not all participants are able to express themselves verbally; some users have a preference for visual expression (Guillemin, 2004). Another advantage is that visual methods may improve the interview process by breaking the ice, prompting memory, improving the content of the interview while helping establish rapport and a shared understanding with the user (Harper, 2002; Bagnoli, 2009).

The use of images can enable the participant to control the interview process, bringing out issues that are meaningful to them (Frith et al., 2005). This also elicits details that might otherwise be difficult to talk about leading to the disclosure of more sensitive issues and details (Bagnoli, 2009). The process of producing a visual image allows participants time to reflect on the topic being explored, which may not only produce rich and insightful images but may inform a more detailed interview. Use of this novel medium also provides participants with the opportunity to reflect on their experience in different ways. This has been described as 'breaking the frame' of experience (Harper, 2002).

Having children create depictions as a way to mirror what is in their minds is a common technique used in psychology. Research into children's drawings has focused on three main areas: (a) the internal structure and visual realism of children's depictions (e.g., Cox, 1992); (b) the perceptual, cognitive, and motor processes involved in producing a drawing (e.g., Freeman, 1980); and (c) the reliability and validity of the interpretation of children's drawings (e.g., Hammer, 1997).

Depictions of the human figure can also reflect a child's social world. La Voy and colleagues (2001) explored the idea that children from different cultural backgrounds may represent cultural differences in their drawings, because culture permeates a child's representations of people. Differences across nations indicated that American children drew more smiles than did Japanese children, whom in turn drew more details as well as larger figures (La Voy et al., 2001). Similarly, Case and Okamoto (1996) showed that there are cultural differences between Chinese and Canadian children's drawings. These findings suggest that children's drawings not only reflect representational development but a child's understanding of self and culture as well.

Having students create depictions of characters and games, is a way to tap into their minds and establish their expectations of pedagogical characters and games. This is an increasingly common technique and has been implemented for learning systems and games for mathematics education. For instance, Grawemeyer and colleagues (2012) managed to have participants within the autism spectrum express and externalize their individual ideas for an educational pedagogical agent for a mathematics educational game, and to combine their individual ideas with the ideas of others in small groups. Students created their own designs and also studied other students' drawings, eventually creating a common prototype.

Informed Consent

Approval for this research was acquired from the Internal Review Board (IRB) at the University of Massachusetts-Amherst under Professor Woolf's Certificate of Human Subjects Approval issued on June 1, 2016. See APPENDIX A. Parent consent and student assent forms were used, see APPENDICES B and C.

Prior to the trials, parents of the participants received a Parental Consent Form that explained the scope of the research being conducted, see APPENDIX B. If a parent chose not to sign the research consent form, the student was still able to participate in the MathSpring workshop, but their data was not used.

At the time of the trial, upon starting their computing session each student was presented with an online informative Student Assent Form so that participants were able to make an informed decision about whether or not they wanted to participate in the research project, see APPENDIX C. Students were told who was doing the research, why they were being asked to take part in the study, the risks involved, the benefits of participating and how researchers would protect their confidentiality. Additionally, students were informed that they could withdraw from the experiment at any time and without giving a reason. Once they understood the nature of the research and gave their consent they were free to participate in the study. If a student did not agree to the online student assent form, the student was able to still participate in the workshop, but their data was not used.

Case Study

Design

For the case study, in July 2016, a two-day MathSpring workshop trial took place in a University of Massachusetts personal computer (PC) computer lab with approximately fifteen incoming eight-grade students. Each workshop session was two hours long and the same students participated in both days ($N = 13$).

Participants

The participants were from the Girls Inc. of Holyoke Camp Eureka summer program. Fifteen incoming eighth-grade students were scheduled to participate in the case study, though only 13 completed all of the activities. Many of the girls were Hispanic students. Most of the Hispanic students identified as Puerto Rican and many of them spoke English as a second language, and thus were English language learners (ELLs). Hispanic ELL students were chosen for this study because they are one of the most vulnerable populations of math learners in the U.S. As previously noted, Reardon et al (2009) reports that Hispanic students enter kindergarten with much lower average math skills, compared to non-Hispanic Caucasian students. It is hoped that this population of learners may provide descriptions of their experiences that will lead to ideas for how to improve the ITS companion design so that it will potentially positively influence all math learners, especially Hispanic ELL students.

Materials

For the case study, following a MathSpring (MS) session, participants designed a learning companion (LC) with the My Blue Robot avatar design application via https://mybluerobot.com/create-your-own-avatar/. Then twelve semi-structured one-on-one interviews with the participants about the utility of the MS LC and the features of the student created learning companion designs were conducted along with a six-participant focus group interview about the activity process.

Procedure

In the case study, following a MathSpring session, participants created a learning companion with the My Blue Robot avatar creation program and then they were interviewed one-on-one about their opinion of the MathSpring learning companion and about their learning companion design by the researcher in English. There was also a focus group interview with approximately six participants about the overall learning companion design activity process. The focus group interview was used along with the one-on-one interviews in order to inform the main study.

At the beginning of the UMass MathSpring workshop, the researcher introduced herself to the students and explained the scope of the research study. It was explained that, in part, the purpose of the study was to understand how to improve the learning companion design and interactions in MathSpring to potentially have a positive impact on affect and learning outcomes for all math students. Then participation was elicited from students to volunteer to interview one-on-one with the researcher about their learning companion design.

Following the MathSpring session, participants completed a companion design activity using the My Blue Robot website. The procedure for the My Blue Robot design activity was to go to the My Blue Robot website (https://mybluerobot.com/create-your-own-avatar/) and design a learning companion that students can learn from. Then the student learning companion designs were screen captured and uploaded to a Google folder. The My Blue Robot learning companion design activity produced images that were analyzed to answer RQ#4 – 'Are the characteristics of the Hispanic ELL student designed learning companions similar or different to the student?'

Subsequent to the design activity, participants were interviewed about their opinions about the MathSpring learning companion, to what degree they identify with how the MathSpring companion looks, sounds and interacts and also about their learning companion design. The qualitative results from the interviews were used to answer RQ#1 – 'How do Hispanic ELL students describe the design of how the MathSpring pedagogical agent looks, sounds and what they say?' and used to inform the creation of a survey for the bigger main study. The focus group interview qualitative data was used to review the companion design activity and inform any possible changes in process for the bigger main study.

In addition to asking about how the MathSpring learning companion should look, sound and say in order for the students to connect with them, the interview questions also explored what roles the students want the learning companions to fulfill, what they want companions to do for them, and how and why.

The following interview questions focused on the students' opinions about both the current and the student-designed MathSpring pedagogical agent:

CS_Q1: 'What do you think of the current learning companion in MathSpring? How does she sound? Look like?'

CS_Q2: 'Think of students that speak a language other than English at home, what part of MathSpring do you think they will have most trouble understanding?'

CS_Q3: 'What did you enjoy about designing your own learning companion?'

CS_Q4: 'What can you tell me about the avatar/learning companion that you designed (age, gender, race, ethnicity, clothes and hairstyle)?'

CS_Q5: 'Are these characteristics similar or different from you? Why?'

CS_Q6: 'What should your learning companion sound like?'

CS_Q7: 'What should your learning companion say?'

CS_Q8: 'What should your learning companion do? How can your learning companion help you learn Math?'

Analysis.

The researcher analyzed the case study interview data from the New England unassisted. Qualitative thematic data analysis was used to evaluate the student responses from the case study. Thematic analysis is the process of identifying patterns or themes within qualitative data (Braun & Clark; 2006). The goal of thematic analysis is to identify themes, i.e. patterns in the data that are important or interesting and to use the themes at both the semantic and latent levels, looking to move beyond describing what is said to interpreting and explaining it. What counts as a theme is that it is something that captures key ideas about the data in relation to the research question and that represents some level of patterned response or meaning within the data set (Braun and Clarke, 2006, p.82). Braun and Clarke (2006) point out that patterns are identified through a rigorous process of data familiarization, data coding, and theme development and revision.

The researcher became familiar with the data by listening to audio recordings of the interviews and then by transcribing them. Then, for each case study interview question the researcher reduced the data into themes through the process of coding, developing themes and representing the data. After codes were generated, the researcher searched for themes within the codes. Then, the themes were reviewed and compared for similarities and difference. The results describe, compare and relate the themes for each question.

Qualitative findings from the case study CS_Q1 question were used to answer **RQ#1** – 'How do Hispanic ELL students describe the design of how the MathSpring pedagogical agent looks, sounds and what they say?'. The interview results were also used to inform the mixed-methods survey for the main study in Southern California and in New England. The data analysis from the case study interview questions (CS_Q1-CS_Q9) about the students' perceived utility of the MathSpring pedagogical agent and about how they relate to the avatar/learning companion designs that they created are below:

CS_Q1: 'What do you think of the current learning companion in MathSpring? How does she sound? Look like?'

The findings from the analysis of CS_Q1 were used to answer RQ#1. Using qualitative thematic data analysis to analyze CS_Q1, the codes of students' responses emerged into positive and negative themes. The positive codes associated with Jane the MS LC were; 'smart', 'supportive', 'helpful' and 'normal'. The negative codes associated with why students did not like Jane the MS LC were: 'boring', 'not noticeable' and 'not realistic'. Associated student responses are featured in the Results chapter, Chapter V.

CS_Q2: 'Think of students that speak a language other than English at home, what part of MathSpring do you think they will have most trouble understanding?'

There was not a lot of response to this question, the codes were organized into themes about the parts of MathSpring to translate and who can benefit from the translation. Students said there should be translation of the math problems and hints along with the emotion (affect) questions for both students and parents.

CS_Q3: 'What did you enjoy about designing your own learning companion?'

The codes from the responses to this question were organized into 'look like me' and 'customizable' themes. The codes associated with the 'look like me' theme were; 'looks like me', 'see myself' and 'symbolize myself'. The codes associated with the 'customizable theme' were; 'customize' and 'change'.

Students who said that they enjoyed designing the companion to look like themselves said: "I like how she looks, I can see myself" and "I made her to look like me". Students who said that they enjoyed designing the companion because it is customizable and changeable said: "It is pretty cool because it is customizable", "I like changing it and thinking about what kind of person it's going to be." and "I can change whatever I want and symbolizes myself.".

CS_Q4: 'What can you tell me about the avatar/learning companion that you designed (age, gender, race, ethnicity, clothes and hairstyle)?'

The codes from the responses to this question emerged into 'relatable' and 'reflection' themes. The codes associated with the 'relatable theme were: 'smart', 'age' and 'gender'. The codes associated with the 'reflection' theme were: 'reflect', 'looks like me' and 'copy'.

Students indicated that their learning companion is relatable. PCS_3 said: "Well she kind of looks like me because of her light eyes and her hair is straightened. I put her my skin color and obviously I'm not white. She can relate to people like us because she had straightened hair like some white people and she has my skin color and light eyes. She is a mix and can relate to many people.". PCS_2 also noted: "The person would be like 24 to 38 age person because that is young, not to be insulting or anything but you know sometimes the older teachers don't get us and are not as relatable, younger teachers are better. I assume she's Hispanic." Additionally, PCS_6 said: "She is 13 but everybody thinks that she is older. Her race is African American and a little bit of Caribbean. Her clothes she has a little flared back top to make it seem like she doesn't have to be a girl she could wear boys clothes. That is why I chose the open front shirt, that is non-gender conforming. I wanted to do something where anybody could relate, they don't have to have the clothes of a girl or of a boy to symbolize their gender."

Many students also expressed: their learning companion is a reflection of themselves and/or looks like them. PCS_5 said: “I designed a white avatar I tried to copy me almost but too much, I changed the eyes to blue and her skin is a little bit more pale than mine and her hair is darker. I pick this combination because it is not as common to have blue eyes and dark hair. She is a mix“. PCS_1 also noted: “I made her kind of like me because I’m really exciting and I like to joke. She’s 13, she’s Puerto Rican and Black. She doesn’t have just one culture because she’s mixed.”. Additionally, PCS_10 described: “She is 14 she's a Christian and Catholic. Her hair is black and she has bangs that are not too neat. I'm not done yet I want to try to make her feel how we feel. Like something that could reflect off of us and be the way she's feeling. I want her to reflect the emotions of how we are feeling. then when somebody walks by they can tell how I am feeling by looking at her. She is a reflection of me.” These findings will be used to help answer **RQ#5 –** ‘How do Hispanic ELL students describe their learning companion designs and why they made their design choices?’.

CS_Q5: ‘Are these characteristics similar or different from you? Why?’

The codes from the responses to this question fell into a ‘similar’ theme. The codes were: ‘similar’, like me’, ‘familiar’ and ‘reflection’. There were no codes from these responses that mapped to a ‘different’ theme.

PCS_9 reported: “She is similar to me because I am a mix. I am something and Italian, Protestant and English. So she’s like me in that way.” PCS_1 also expressed: “My avatar is just like me.” Furthermore, PCS_2 said: “Younger, like I am. Closer to my age. I made her similar to me because that seems familiar. Additionally, PCS_6 noted: “She looks like me, I made her similar to me so that I can relate to her.” Finally, PCS_10 expressed: “She is similar to me, to reflect me.”

CS_Q6: ‘What should your learning companion sound like?’

The codes from the responses to this question emerged into ‘familiar’ and ‘encouraging’ themes. The codes associated with the ‘familiar’ theme were: ‘like me’ and ‘relatable’ and ‘natural’. The codes associated with the ‘encouraging’ theme were: ‘positive’, ‘encouraging’, and ‘nice’.

Students felt that the learning companion should sound familiar. PCS_5 said: “She should ask if you need help or if you’re having issues. She would have an accent that is a mix of everybody’s, but it is clear.” PCS_6 also expressed: “I feel she should sound mellow and sound natural, not operated. Someone you can relate to or talk to so when you can look at in the game and go like oh my God I can relate to her or if she's so fashionable and cool.” Additionally, PCS_10 noted: “She should sound like me - nice, complimentative. [sic]”

Students also felt that the learning companion should sound encouraging and provide positive reinforcement. PCS_11 said that the LC should sound positive: “Positive, helps others.” PCS_9 also reported: “She should have a positive attitude and encourage them to keep learning even if they get something wrong.” Additionally, PCS_1 expressed: "She should sound exciting and encouraging." Finally, PCS_3 said: “Encouraging, keep going and try your best. Math can sometimes get boring after a while if your teacher doesn’t keep you interested in it and gives fun activities and rewards.”

CS_Q7: ‘What should your learning companion say?’

The codes from the responses to this question emerged into ‘scaffold learning’ and ‘more interactive’ themes. The codes associated with the ‘scaffold learning’ theme were: ‘hints’, ‘explain and ‘understand’. The codes associated with the ‘more interactive’ theme were: ‘gesture’, ‘asks’, ‘give’ and ‘show’.

Students felt that the learning companion should scaffold learning. PCS_11 said: “Give hints, no answers, just help.” PCS_9 also noted: “It’s okay if you get one question wrong because we’ll show you what you did wrong and how to get the right answer for the next problem.” Additionally, PCS_3 expressed that the LC should, “Explain the math step.” Furthermore, PCS_2 said: “Well instead of saying wow, you were excellent, I think if you get something wrong the companion should pop up into the center of the screen instead of on the side and she can talk to you and help you understand why you got your problem wrong.” Finally, PCS_6 noted the LC should “Ask if you need help.”

Students also thought that the learning companion should be more interactive. PCS_1 said: “She should say jokes.” PCS_2 also noted: “sometimes she could go to the side and gesture by using her hands to point to examples on the side of her.” Additionally, PCS_10 expressed: “She should be interactive. When somebody walks by she should say hi, She should compliment somebody when they walk by about what they are wearing."

CS_Q8: 'What should your learning companion do? How can your learning companion help you learn Math?'

The codes from the responses to this question also emerged into 'scaffold learning' and 'more interactive' themes. The codes associated with this 'scaffold learning' theme were: ' tips', 'pointer's and 'hints'. The codes associated with this 'more interactive' theme were: 'rewards', 'quests' 'move' and 'gesture'.

Students felt that the learning companion should scaffold learning. PCS_11 said: "She can give pointers to help you understand the different options on how to learn" and PCS_9 expressed: "she should give you helpful tips on how to improve the math skills". Students also thought that the learning companion should be more interactive and PCS_3 noted: "she should give rewards like points so that that you can buy plants for the garden and have a plant for each topic", PCS_10 reported, "she should be interactive and move and use gestures" and PCS_2 said: "The avatar should move and use gestures. She should walk out and use her hands and to point to examples".

Main Study

Design

The main study consisted of a classroom trial during December 2016 and a second UMass workshop trial during July 2017. The classroom trial took place in an urban school district in Southern California with thirty-nine (*N* = 39) sixth-grade students in math classes for two class sessions. The workshop trial took place during a two-day MathSpring workshop in a University of Massachusetts personal computer (PC) lab with eighteen incoming eighth-grade students. Each workshop session was two hours long and different students participated during each day, for a total of thirty-seven students (*N* = 37).

Participants

In total, seventy-six (*N*=76) mostly Hispanic middle-school aged students (*N*= 61) participated in the main study. There were fifty-six females (*N*= 56) and twenty males (N = 20); these numbers are skewed because all of the participants in the New England class were females. Additionally, sixty-one students in the study were Hispanic (*N*= 61) and fifteen were Caucasian (*N*= 15) while twenty-four were ELL students (*N* = 24) and fifty-two were non-ELL students (*N* = 52). All of the English language learner (ELL) students in the study were Hispanic but unlike the other Hispanic students their first or primary language was Spanish. Many of their families primarily spoke Spanish at home as opposed to the other Hispanic students whose primary and first language was English.

Of the seventy-six participants, thirty-nine (*N* = 39) were sixth grade students from an urban school district in Southern California (P_CA1 – P_CA39) and thirty-seven (*N* = 37) were incoming eighth grade public school female students from New England (P_NE1 – P_NE37). Most of the classroom trial students from

California were Hispanic and identified as Mexican Americans (*N*=35) and many of the students were identified as ELLs (*N*=14). The UMass workshop participants were from the Girls Inc. of Holyoke Camp Eureka summer program. Many of the girls were Hispanic students and identified as Puerto Rican (*N*=26) and some of them were ELLs (*N*=10).

Materials

For the main study, following their MathSpring session all participants from both the classroom and the workshop trials designed a learning companion with the My Blue Robot avatar design program. Then they took an online survey that was informed by the interviews from the case study. The survey questions were designed to measure two constructs 1) 'Did the MathSpring Learning Companion help you learn? How?' and 2) 'How did you design your Learning Companion? Why?' The survey consisted of both 5-point Likert scale and open response questions. The Likert items ranged from 1 (strongly disagree) to 5 (strongly agree).

The survey questions were stated in both English and Spanish and used to create the 'JaneHelpful' subscale that measure the first construct (C1), 'Did the MathSpring Learning Companion help you learn? How?', were:

1. I liked using the Learning Companion, Jane, in MathSpring because she helped me understand. (Me gustó usando el Compañero de aprendizaje, Jane, en MathSpring porque ella me ayudó a entender.)

2. Jane was not that useful to me, so I did not use her. (Jane no era tan útil para mí, así que no la usé.)
3. I think Jane was a very helpful part of MathSpring. (Creo que Jane era una parte muy útil de MathSpring.)

The 'JaneHelpful' subscale open response question was:

4. If you thought Jane was helpful, Why? (Si usted pensó que Jane era muy útil, ¿Por qué?)

The Likert survey questions used to create the 'AvatarLooksLikeMe' subscale that measured the second construct (C2), 'How did you design your Learning Companion? Why?', were:

5. The Learning Companion/Avatar that I created looks a lot like me. (El compañero de aprendizaje / Avatar que creé se parece mucho a mí.)
6. The Learning Companion that I designed looks nothing like me. (El compañero de aprendizaje que diseñé parece en nada a mí.)
7. The Learning Companion that I created has a lot of my characteristics. (El compañero de aprendizaje que he creado tiene un montón de mis características.)

The 'AvatarLooksLikeMe' subscale open response questions were:

8. Describe your Learning Companion. (Describa su compañero de aprendizaje.)

9. Why did you design your Learning Companion the way you did? (¿Por qué el diseño de su compañero de aprendizaje de la manera que lo hizo?)

Principal components factor analysis was performed on the six Likert survey items to verify the two constructs of the scale. Factor analysis confirmed that three of the survey Likert items mapped to the 'JaneHelpful' construct (C1) and three mapped to the 'AvatarLooksLikeMe' construct (C2). A Cronbach's alpha reliability analysis was also carried out on the scale as a whole and on the two subscale constructs to access the internal consistency of the survey. Finally, standard deviation and means were also determined for each instrument item. The factor analysis measures, reliability scores and item standard deviations and means are all reported in the Results Chapter, Chapter V.

Procedure

The data collected and the RQs that the data answered are presented in Table 2. In this study, after students used the MathSpring ITS, they created a learning companion with the My Blue Robot avatar creation program and then they were surveyed about their opinion of the MathSpring learning companion and about their learning companion design.

As in the case study, at the beginning of the trial, the researcher introduced themselves and explained the scope of the study. Again, it was explained that the purpose of the study was to understand how to inform ways to improve the companion design and interactions in the MathSpring ITS to potentially have a positive impact on affect and learning outcomes for all math students.

After students engaged with MathSpring they participated in the learning companion design activity. The My Blue Robot learning companion design activity produced images that were analyzed to answer RQ#4 - Are the characteristics of the Hispanic ELL student designed learning companions similar or different to the student?

The activity directions were provided on the following website: https://sites.google.com/view/mathspringlc/home, see Figure 3. The activity consisted of designing a learning companion that students can learn from with the My Blue Robot avatar creation program - https://mybluerobot.com/create-your-own-avatar/. After students created a learning companion with My Blue Robot, they saved the image to their desktops and then they uploaded them to a shared Google folder.

Following the learning companion design activity, the students took a survey about the utility of the MathSpring pedagogical agent and their learning companion designs. The survey questions were provided to the students in English and Spanish. The responses to both the quantitative and qualitative survey data were analyzed to answer the research questions.

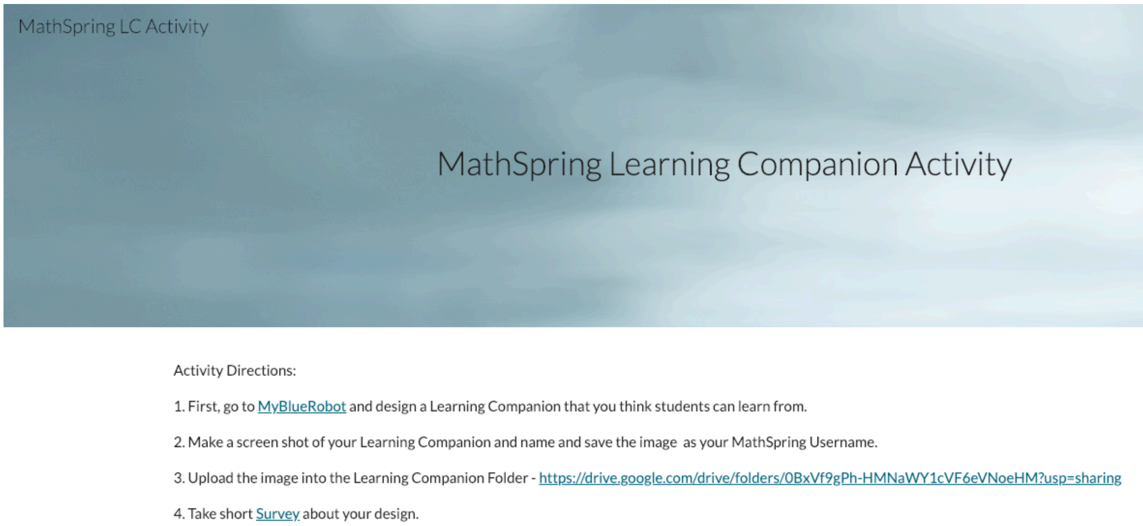


Figure 3: Activity Webpage and Directions.

Analysis

This mixed-method research features both qualitative and quantitative analysis. Table 2 presents the RQs, data collected, and analysis used on the data to answer the RQs. See Table 2.

Table 2: Research Questions, Data and Analysis

Research Question	Data	Analysis
RQ#1: How do Hispanic ELL students describe the design of how the MathSpring pedagogical agent looks, sounds and what they say?	Interviews	Grounded Theory (GT) Qualitative thematic data analysis
RQ#2: How do Hispanic ELL students perceive the utility of the pedagogical agent and learning math in MathSpring? Do students find the MS pedagogical agent useful?	Surveys	Thematic image analysis; Quantitative statistical analysis
RQ#3: What aspects of pedagogical agents do Hispanic students find helpful and in what ways?	Surveys	GT Qualitative thematic analysis
RQ#4: Are the characteristics of the	My Blue Robot	GT Qualitative thematic

Hispanic ELL student designed learning companions similar or different to the student?	avatar design activity	analysis; Quantitative statistical analysis
RQ#5: How do Hispanic ELL students describe their student created learning companion designs and how do they explain their design choices?	Surveys	GT Qualitative thematic analysis

The degree to which the students found the MathSpring APA useful and the extent to which participants identified with their LC designs are were determined by comparative quantitative methods and are presented in Chapter V, Results. The overall scale consisted of six Likert items that were measured on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). Factor analysis confirmed that three of the survey Likert items mapped to the 'JaneHelpful' construct (C1) and three mapped to the 'AvatarLooksLikeMe' construct (C2) as featured in Chapter V, Results, Table 14. Prior to analysis, items 2 and 6, 'Jane was not that useful to me, so I did not use her.' and 'The Learning Companion that I designed looks nothing like me.' were reverse coded. Comparative analysis was run between the Caucasian and Hispanic students and the ELL and non-ELL students on the two constructs.

Next, Cronbach's reliability was also run to determine and showed a good internal consistency on the whole and 2 sub-scales. Then, standard deviations and means were run for each for each subscale for all students, Hispanic, Caucasian, ELL and Non-ELL students and reported in Table 14. After that, independent sample t-tests were conducted to compare whether there is a difference between how

Hispanic students and Caucasian students find the MathSpring LC Jane helpful and to compare whether there is a difference exists between how ELL students and non-ELL students find the learning companion Jane in term of helpfulness. Finally, an independent-samples t-test was conducted to compare whether a difference exists between how similar the Hispanic students' and the Caucasian students' LC avatar designs are to themselves and to compare whether a difference exits between how similar the ELL students' and the non-ELL students' LCs designs are to themselves. Lastly, an independent-samples t-test was conducted to compare whether a difference exists between the ELL students' and the non-ELL students' LCs designs.

Then all of the qualitative interview and survey data was thematically analyzed and used to triangulate and shed light on the quantitative survey data. The quantitative analysis was conducted with the Statistical Package for the Social Scientist (SPSS 25). The qualitative interview data was analyzed with nVivo, a qualitative data analysis (QDA) computer software package produced by QSR International.

The qualitative interview audio files were transcribed and imported in nVivo. Thematic data analysis was used to extract meaning from both the open-ended survey questions and the semi-structured interview questions using Corbin and Strauss's (2008) open, axial and selective coding methods. nVivo was used to code and categorize the data. The data was broken down into discrete parts, closely examined and compared for similarities and differences in order to understand the emerging themes.

Additionally, thematic image analysis was used to look at the student learning companion designs created with My Blue Robot. Student learning companion designs were compared for similarities and differences in order to understand emerging themes. Focused qualitative findings were used to bolster the quantitative results. Hispanic ELL student utterances and images were used to dig deeper into the quantitative results.

Grounded Theory QDA

Grounded theory qualitative data analysis (QDA) is used to analyze data from human respondents. Drawing on the open coding methods described by Corbin and Strauss, participant responses are inductively analyzed for concepts, categories and themes drawing on the open coding methods. Open coding is the part of analysis that pertains specifically to the naming and categorizing of phenomena through close examination of the data. During open coding the data are broken down into discrete parts closely examined, compared for similarities and differences, and questions are asked about the phenomena as reflected in the data (Corbin and Strauss, 1990).

Following open coding, axial coding is performed. Axial coding is the process of relating codes (categories and properties) to each other, via a combination of inductive and deductive thinking. It is the process of finding what the different open codes have in common, and what the categories have in common with sub-categories. Identifying relationships between open codes and combining original codes into major categories and defining sub-categories and their relations to the others.

Finally, selective coding is the process of choosing main categories to be the core categories that relate to all of the other categories. The essential idea is to develop a single storyline around which everything else is draped. Strauss and Corbin define selective coding as "the process of selecting the central or core category, systematically relating it to other categories, validating those relationships, and filling in categories that need further refinement and development" (p.116).

QDA Open Coding Protocol

A Grounded Theory QDA protocol inspired by Corbin and Strauss (1990) was used to identify features in the data and to develop a theory that explains the reason students found the MathSpring LC useful and how and why they identify with their student designed their LC's.

In this study, students self-reported on a target concept via 1-5 point Likert scale. Then they were asked to explain, "Why is that?" with an open survey response. Grounded theory QDA was used to extract features from the student self-reported responses about the reason students found the MS LC useful/not useful (Q1) and how (Q2) and why (Q3) they designed their LCs. Students' open responses to Q1, 2 and 3 were inductively analyzed for concepts, categories and themes drawing on the open coding methods described by Corbin and Strauss. Open coding is the part of analysis that pertains specifically to the naming and categorizing of phenomena through close examination of the data. During open coding the data was broken down into discrete parts closely examined, compared for similarities and differences, and questions were asked about the phenomena as reflected in the data (Corbin and Strauss, 1990).

Student utterances for the three open survey responses (Q1-'If you thought Jane was helpful, Why?', Q2-'Describe your Learning Companion.', and Q3-'Why did you design your Learning Companion the way you did?') were open-coded and labeled into meaningful, descriptive categories by five graduate student researchers (R1, R2, R3, R4 and R5) that reflected students' feedback. R1, the main researcher and author of this paper, and three of the graduate researchers worked in the College of Information and Computer Sciences MS lab and two were from the College of Education.

The first round of open coding categories can be found in Tables 3, 4 and 5. See Tables 3, 4 and 5. Then, the five researchers had a discussion to compare similarities of their categories and to agree on a best coding scheme. See Appendix D for transcription of researcher open coding discussion. Also, see Tables 6, 7 and 8 for the categories of the agreed upon finalized coding schemes for Q1, Q2 and Q3.

Next, two of the five researchers (R1 and R2) used the new agreed upon categories to re-code the questions. For each of the three questions (Q1, Q2 and Q3), R1 and R2 first coded twenty utterances with the newly agreed upon best coding schemes. After that, an inter-rater reliability analysis using the Kappa statistic (κ) was performed to determine consistency among the raters. Cohen's was run to determine if there was agreement between R1 and R2 and checked to be above 0.6 before R1 and R2 coded the full-set of utterances. There was substantial agreement between R1 and R2 on the first twenty Q1 utterances, the interrater reliability for the raters was found to be κ =.714, ρ<.0005. There was also substantial agreement between R1 and R2 on the first twenty Q2 utterances, the interrater reliability for the raters was found to be κ =.685, ρ<.0005. Additionally, there was substantial agreement between R1 and R2 on the first twenty Q3 utterances, the interrater reliability for the raters was found to be κ =.763, ρ<.0005.

Then, for each question Cohen's κ was conducted to determine the inter-rater reliability agreement between the codes assigned by R1 and R2 to the full set of student utterances, checking that it continued to be above 0.7. The interrater reliability between R1 and R2 on the full set of Q1 student utterances was substantial and found to be κ =.734, ρ<.0005. The interrater reliability between R1 and R2 on the full set of Q2 utterances was also substantial and found to be κ =.728, ρ<.0005. Additionally, the interrater reliability between R1 and R2 on the full set of

Q3 utterances was in almost perfect agreement substantial and found to be κ =.881, ρ<.0005.

Following the Grounded Theory QDA open coding, axial and selective coding was also performed on the three open response questions and is shown in Tables 9, 10 and 11. Finally, the emerging narratives from Q1-Q3 are discussed in term of the figured worlds theoretical framework in the Discussion, Section 6.

QDA Open Coding Details

For **Q1-'If you thought Jane was helpful, Why?'** the first round of open coding categories derived by all 5 researchers (R1-R5) are displayed in Table 3.

Table 3: Helpfulness of LC: Open Coding

Q1- If you thought Jane was helpful, Why?

5 coders (R1-R5) open coding categories	**New open code scheme**	**Properties**	**Examples of participants' words**
motivational-reward, motivated participation, motivating, encouragement	Positive reinforcement	If a student says that the LC provided encouragement, motivation or comfort.	"She encouraged me to keep trying the math.", "I thought that Jane was helpful because she will either say ''Great job'' and others to say too you because when you get the problems right she will say those. And if you get the problems wrong she will just say ''its ok you can do better'' or ''at least you tried''.
guidance, math input, gave explanation, provided guidance; supported learning; help understand	Better understanding	If a student says that the LC provided support and guided learning (scaffolding).	"I thought Jane was very helpful because she made me understand things about the question that helped me a lot." and "She was helpful due to me not knowing a decimal problem she gave me an example"
advance learning, supported learning, better grades, helpful	Better performance	If a student says that the LC helped improve math performance.	"He helped me get better grades than i usually get" and "he helped me learn new things and got me better grades"
generally helpful, agreed, helpful, useful	General positive experience	If a student says anything suggesting	"she was very helpful because she is a good helper"'

		that they LC was generally helpful.	
learning companion features, personality, smart, intelligent	Feature of the learning companion	If a student attributes the LC features to usefulness.	"Because she is strong smart and bold", "Jane was helpful because she read.", "Jane was helpful because she encouraged me to do better and to help me learn better she also read the question for me." and "I thought she was helpful because she is smart."
system features	Feature of the system	If the student says LC guided them to use system features.	"She helped me learn that there was [sic] hints videos and other things.", "she gave hints if you were struggling" and "She was help full because so showed you examples of your problem. That helped do your problem."
fun, engaging, fun learning process	Engaging	If the student says anything suggesting that the LC was engaging.	"She made learning fun."
she/me	She/Me connection	If the student uses he/she/me/us comments to refer to LC.	"Jane was helpful because she encouraged me to do better and to help me learn better she also read the question for me."
feel	Affect state	If the student contributes a feeling state to interacting with LC.	"I thought Jane was helpful because when Jane said good job it makes me feel good that I did it.", "She made feel confedent." [sic], "She made me fell that I'm not alone learning, and she mad me fell confident. [sic]" and "She made me feel like I can keep on going and I won't get anything wrong because she said that I was excellent and I was very good at math."
not helpful, unhelpful,	Not helpful	If the student says the LC is not helpful.	"I didn't really use her that much so she was not helpful." and "I did not think she was helpful."
indifferent,	Indifferent	If the student is indifferent about LC.	"because she kind of helps." and "I can't really explain but she was helpful"

Then, for **Q2-'Describe your Learning Companion.'** the first round of open coding categories derived by all 5 researchers (R1-R5) are shown below in Table 4.

Table 4: Descriptions of LCs: Open Coding Categories

Q2- Describe your Learning Companion.

5 coders open coding categories	New open code scheme	Properties	Examples of participants' words
like me, resembled themself, reflected themself, modeled on self	Self-replication (like me)	If a student attributes their LC design to look like themselves.	"He has my skin tone, my hair, my eyes, my eyebrows, my ears, the shape of my head and my favorite color on him and surrounding him.", "I made my learning companion look like me", "My learning companion is a female she has black-brown hair like me, she has light skin, she has brown eyes also like me, and she wears black sort of like me.", "My learning companion has glasses hair similar to mine and a blue shirt."
physical feature description of: eyes, glasses, nose, lips, mouth, hair, skin or clothes	Physical features	If a student describes their LC design in terms of physical features.	"My learning companion has medium skin. It has dark hair, and it's medium in length. Also it wears a dark colored hoodie. It has brown eyes and a small smile."
personality descriptors, personality, helpful, supportive	Personality traits	If a student says that their design includes personality traits, i.e., helpful, encouraging, supportive or comforting.	"My learning companion is a guy who is smart", "happy but shy in home gets crazy but in school no.", "its strong smart and bold ", "My learning companion i would have to say is very coorapitive.", "I would describe and make it as a funny, nice, and pretty puerto rican woman with dark hair."
like family member, like friend, modeled after family member, modeled on acquaintance	Familiar characteristics	If a student says that they designed their LC to be familiar, like a friend, family member or favorite character.	"IT looks like my uncle thats what i was aiming for.", "it looks like my best friend Jordan", "it looks like my mom", "she looks like my mother has red eyes and she is beutiful"
creative, imaginative, art, inspired	Imaginative creativity	If a student attributes their LC design to their imagination or creativity.	"Art", "He has glasses. He looks like he's from an anime.", "He has glasses. He looks like he's from an anime."
reflected gender, female, male,	Gender identity	If a student mentions the gender of their character design.	"My learning companion is a girl because i'm a girl and it's what i wanted","his name is jake he a transgender because he is a she and shes a strong tuff girl/boy.", "My learning companion does not look exactly like a 'male' or 'female', and seems to be somewhere between feminine and masculine. They have turquoise colored hair, feminine eyes, a square jawline, and

			is wearing a sort of polo shirt with an undershirt between it, to seem more gender neutral.", "My learning companion is literally a genderbend me."She is a girl. I made her just out of my mind. She is white with wavy golden-brown hair, violet eyes, short eyelashes and a white hoodie."
fun, easy, good, helpful, cool	Evaluation	If a student attributes an evaluation to their LC design.	Fun, easy, good, helpful, cool

Finally, for **Q3-'Why did you design your Learning Companion the way you did?'** the first round of open coding categories derived by all 5 researchers (R1-R5) are presented below in Table 5.

Table 5: Reasons for LC Designs: Open Coding Categories

Q3 - Why did you design your Learning Companion the way you did?

5 coders open coding categories	New open code scheme	Properties	Examples of participants' words
modeled on self, my personality, reflective of self, like me	Self replication (like me)	If a student says they made their LC design to look like themselves.	"I designed it like this because she looks like me, a student that loves to help and learn math.", "I designed my Learning Companion the way I did because she looks like me and I'm used to how I look so the only way I thought I could design it with my features.", "I wanted him to look like me and I will make him have all my personalities and my characterisics."
motivational, comforting, encouraging	Positive reinforcement	If a student says that they designed their LC to provide encouragement, motivation or comfort.	"I wanted my Learning Companions to look like they wouldn't look like they'd get all mad at you for failing a question or something. I wanted them to look chill if you got a question wrong.", "I made her like that so the student would feel better when he or she are getting frustrated or when they are getting upset that they got the problem wrong."
supportive, learn more, help	Better understanding	If a student says that they designed their LC to support and guide learning.	"It made me feel like i could learn from it.", "

pretty, attractive, beautiful, look good	Attractive	If a student refers to their LC design is attractive.	"The way i designed her she looked pretty and she had a happy gesture on her face so i really liked her", "i just wanted him to look good ", "I designed my learning companion the way I did because I thought she looked pretty."
cool, interesting, not boring, motivating	Cool	If a student refers to their LC design as cool.	"its looks cool so kids will like it instead of looking like a teacher they hate or something", "
clever, smart intelligent presenting	Smart	If a student says that they designed a smart LC.	"I wanted her like this because she looks like a detective/agent and I like to think that she is an agent or detective of mathematics.", "I designed my learning companion the way I did because I wanted her to look smart and like she knew what she was doing.", "Because he looks smart."
gender nonspecific, gender neutral, universally relatable, gender	Gender identity	If a student mentions the gender of their LC design.	"I wanted them to relate to anyone of any gender or sex in any way.", "because it is not a specific gender", "
replication of a racial group to challenge stereotypes, promote diversity, defy stereotypes, more diverse	Diversity representation	If a student suggests that they designed their LC to be diverse.	"I designed my learning companion the way I did because I am so used to people saying puerto ricans alway cause trouble and are always not smart even though we can be.", "I WANTED IT TO BE MORE DIVERSE. YOU DON'T REALLY SEE MUCH DIVERSITY WHEN IT COMES TO CHARACTERS.", "I designed her the way I did because she is different and not the "NORMAL" of what people may say."
celebrity inspired, replication of favorite character	Favorite character	If a student says that they modeled their LC design after a favorite character.	"He's from a webcomic that's pretty much my whole life, that and he's one of my favourite characters, so he's had a huge impact on me.", "so he could look like my favorite cartoon character ", "she my favorite character form persona 5 { video game }"
friendly, looks like parents, replication of family member, familiar	Familiar characteristics	If a student indicates that their LC design is familiar.	"I wanted to be comfortable so when I see her she kinda reminds me like my parents except I dont have green eyes and I dont wear glasses all the time.", I gave my learning companion the hair style because it is similar to mine and the glasses because my a lot of people in my family wear glasses and for the shirt

			I made it blue because I like the color blue.", "TO look look like my uncle because he helps me alot and hes fun"
creative, imagination	Imaginative creativity	If a student says that they used their creativity or imagination to design their LC.	"i did because i like to be creative", "Because it was the creative side of me."

QDA Finalized Open Codes

Finalized open response codes from the Grounded Theory qualitative data analysis were used to extract meaning from the student self-reported responses to evaluate the impact of the MathSpring APA design (Q1) and the student created LC designs (Q2) (Q3).

For **Q1-'If you thought Jane was helpful, Why?'** a final coding scheme of the following categories was derived by R1-R5 from the themes that emerged and are shown below in Table 6 in the order of most frequent occurrence. The codes are: 'She/Me Connection', 'Positive Reinforcement', 'Better Understanding', 'Better Performance', 'Feature of System', 'Feature of Learning Companion', and 'Feeling', 'General Positive Experience', and 'Not Helpful', 'Indifferent' and 'Miscellaneous', see Table 6. Then, the Q1 final coding scheme was implemented by R1 and R2 and substantial inter-rater reliability agreement existed between R1 and R2 on the first 20 utterances of Q1, $\kappa = .714$. Also, a substantial inter-rater reliability agreement existed between R1 and R2 on the full set of utterances of Q1, $\kappa = .734$. The percentage and the order of most frequent occurrence of the final Q1 codes as implemented by R1 and R2 are displayed in Table 6.

Table 6: Summary of Q1 - Helpfulness of LC: Open Coding

%	Open code	Properties	Examples of participants' words
28	She/Me Connection	If the student uses he/she/me/us comments to refer to LC.	" Jane was helpful because **she** encouraged **me** to do better and to help **me** learn better **she** also read the question for **me**."
14	Positive Reinforcement	If a student says that the LC provided encouragement, motivation or comfort.	"She encouraged me to keep trying the math.", "I thought that Jane was helpful because she will either say ''Great job'' and others to say too you because when you get the problems right she will say those. And if you get the problems wrong she will just say ''its ok you can do better'' or ''at least you tried''.
14	Better Understanding	If a student says that the LC provided support and guided learning (scaffolding).	"I thought Jane was very helpful because she made me understand things about the question that helped me a lot.", "She was helpful due to me not knowing a decimal problem she gave me an example"
9	Better Performance	If a student says that the LC helped improve math performance.	"He helped me get better grades than i usually get", "he helped me learn new things and got me better grades"
8	Feature of the System	If the student says LC guided them to use system features.	"She helped me learn that there was hints videos and other things.", "she gave hints if you were struggling", "She was help full because so showed you examples of your problem. That helped do your problem."
6	Feature of the Learning Companion	If a student attributes the LC features to usefulness.	"Jane was helpful because she read."," Jane was helpful because she encouraged me to do better and to help me learn better she also read the question for me.", "I thought she was helpful because she is smart."
5	Feeling	If the student contributes an affect state to interacting with LC.	"I thought Jane was helpful because when Jane said good job it makes me feel good that I did it.", "She made feel confedent.", "She made me fell that I'm not alone learning, and she mad me fell confident.", "She made me feel like I can keep on going and I won't get anything wrong because she said that I was excellent and I was very good at math."
5	General Positive Experience	If a student says anything suggesting	"she was very helpful because she is a good helper"',

		that they LC was generally helpful.	
4	Not Helpful	If the student says the LC is not helpful.	"I didn't really use her that much so she was not helpful.", "I did not think she was helpful."
3	Indifferent	If the student is indifferent about LC.	"because she kind of helps.", "I can't really explain but she was helpful"
3	Misc	Miscellaneous utterances	

Additionally, for **Q2-'Describe your Learning Companion.'** a final coding scheme of the following categories was derived by R1–R5 from the themes that emerged and are displayed in Table 7. The codes are: 'Physical Features', 'Gender', 'Evaluation' 'Personality', 'Like Me', 'Familiar', 'Imaginative/Creative' and 'Miscellaneous', see Table 7. Then, the Q2 the coding scheme was implemented by R1 and R2 and substantial inter-rater reliability agreement was found between R1 and R2 on the first 20 utterances of Q1, κ = .685. In addition, substantial inter-rater reliability agreement was determined between R1 and R2 on the full set of utterances of Q2, κ = .728. The percentage and the order of most frequent occurrence of the final Q2 codes as implemented by R1 and R2 are displayed in Table 7.

Table 7: Summary of Q2 -Description of LC Open Coding Categories

%	Open code	Properties	Examples of participants' words
29	Physical Features	If a student describes their LC design in terms of physical features.	"My learning companion has medium skin. It has dark hair, and it's medium in length. Also it wears a dark colored hoodie. It has brown eyes and a small smile."

21	Gender	If a student mentions the gender of their character design.	“My learning companion is a girl because i'm a girl and it's what i wanted”, “his name is jake he a transgender because he is a she and shes a strong tuff girl/boy.”, “My learning companion does not look exactly like a 'male' or 'female', and seems to be somewhere between feminine and masculine. They have turquoise colored hair, feminine eyes, a square jawline, and is wearing a sort of polo shirt with an undershirt between it, to seem more gender neutral.”, “My learning companion is literally a genderbend me.“She is a girl. I made her just out of my mind. She is white with wavy golden-brown hair, violet eyes, short eyelashes and a white hoodie.”
15	Evaluation	If a student attributes an evaluation to their LC design.	Fun, easy, good, helpful, cool
13	Personality	If a student says that their LC design includes personality traits, i.e., helpful, encouraging, supportive or comforting.	“My learning companion is a guy who is smart”, “happy but shy in home gets crazy but in school no.”, “its strong smart and bold “, “My learning companion i would have to say is very coorapitive [*sic*].”, “I would describe and make it as a funny, nice, and pretty puerto rican woman with dark hair.”, “My learning character is mostly gonna give the student encouragement and tell very good hints that would help the person know the problem a bit better, if the student still doesn't get it then she will advise the student to use the hint so they can learn the problem. Once the student gets the problem right she will say "Good job" or "Your so smart!" and other nice things like that, when the student gets the problem wrong then she will say "It's okay, try again, we all make mistakes" or "Let's try again, try challenging your brain more to understand." she will encourage the student to try again and try to make them challenge themselves.”
7	Like Me	If a student describes their LC design to look like themselves.	“He has my skin tone, my hair, my eyes, my eyebrows, my ears, the shape of my head and my favorite color on him and surrounding him.”, “I made my learning companion look like me”, “My learning companion is a female she has black-brown hair like me, she has light skin, she has brown eyes also like me, and she wears black sort of like me.”, “My learning companion has glasses hair similar to mine and a blue shirt.”, “She has dark hair like me and ties it up like me she wears black and I do also. The difference we have is I

			have dark eyes also she has green eyes she wears glasses I do also but not often and she has dark skin like me but a little lighter.”
5	Familiar	If a student says that they designed their LC to be familiar, like a friend, family member or favorite character.	“IT looks like my uncle thats what i was aiming for.”, “it looks like my best friend Jordan”, “it looks like my mom”, “she looks like my mother has red eyes and she is beautiful [*sic*].”
5	Imaginative/ creativity	If a student attributes their LC design to their imagination or creativity.	“Art”, “He has glasses. He looks like he's from an anime.”, “He has glasses. He looks like he's from an anime.”
4	Misc	Miscellaneous utterances	

Finally, for **Q3-’Why did you design your Learning Companion the way you did?**’ a coding scheme of the following categories was derived from the themes that emerged and are presented in Table 8 in the order of most frequent occurrence. The codes are ‘Like Me’, ‘Gender’, ‘Positive Reinforcement’, ‘Better Understanding’, ‘Attractive’, ‘Cool’, ‘Smart’, ‘Familiar’, ‘Diversity’, ‘Creative’ and ‘Miscellaneous’, see Table 8. Then, the Q3 the coding scheme was implemented by R1 and R2 and there was near perfect inter-rater reliability agreement between R1 and R2 on the first 20 utterances of Q1, κ = .881 then there was also a substantial inter-rater reliability agreement between R1 and R2 on the full set of utterances of Q1, κ = .763. The percentage and the order of most frequent occurrence of the final Q3 codes as implemented by R1 and R2 are displayed in Table 8.

Table 8: Summary Q3 - Reasons for LC Designs: Open Coding Categories

%	Open code	Properties	Examples of participants’ words

24	Like Me	If a student says they made their LC design to look like themselves.	"I designed it like this because she looks like me, a student that loves to help and learn math.", "I designed my Learning Companion the way I did because she looks like me and I'm used to how I look so the only way I thought I could design it with my features.", "I wanted him to look like me and I will make him have all my personalities and my characterisics."
23	Gender	If a student mentions the gender of their LC design.	"I wanted them to relate to anyone of any gender or sex in any way.", "because it is not a specific gender", "
11	Positive Reinforcement	If a student says that they designed their LC to provide encouragement, motivation or comfort.	"I wanted my Learning Companions to look like they wouldn't look like they'd get all mad at you for failing a question or something. I wanted them to look chill if you got a question wrong.", "I made her like that so the student would feel better when he or she are getting frustrated or when they are getting upset that they got the problem wrong."
9	Better Understanding	If a student says that they designed their LC to support and guide learning.	"It made me feel like i could learn from it.", "
8	Attractive	If a student refers to their LC design is attractive.	"The way i designed her she looked pretty and she had a happy gesture on her face so i really liked her", "i just wanted him to look good ", "I designed my learning companion the way I did because I thought she looked pretty."
7	Cool	If a student refers to their LC design as cool.	"its looks cool so kids will like it instead of looking like a teacher they hate or something", "
5	Familiar	If a student indicates that their LC design is familiar.	"I wanted to be comfortable so when I see her she kinda reminds me like my parents except I dont have green eyes and I dont wear glasses all the time.", I gave my learning companion the hair style because it is similar to mine and the glasses because my a lot of people in my family wear glasses and for the shirt I made it blue because I like the color blue.", "TO look look like my uncle because he helps me alot and hes fun"
5	Smart	If a student says that they designed a smart LC.	"I wanted her like this because she looks like a detective/agent and I like to think that she is an agent or detective of mathematics.", "I designed my learning companion the way I did because I wanted her to look smart and like she knew what she was doing.", "Because he looks smart."
4	Diversity	If a student suggests that they designed their	"I designed my learning companion the way I did because I am so used to people saying puerto ricans alway cause trouble and are always not smart even

		LC to be diverse. (race, culture or gender)	though we can be.", "I WANTED IT TO BE MORE DIVERSE. YOU DON'T REALLY SEE MUCH DIVERSITY WHEN IT COMES TO CHARACTERS.", "I designed her the way I did because she is different and not the "NORMAL" of what people may say."
3	Creative	If a student says that they used their creativity or imagination to design their LC.	"i did because i like to be creative", "Because it was the creative side of me."
2	Misc	Miscellaneous utterances	

QDA Axial Coding

For **Q1 – 'If you thought Jane was helpful, Why?'**, the most predominant open codes were 'She/Me Connection', 'Positive Reinforcement', 'Better Understanding', 'Better Performance', 'Feature of System', 'Feature of Learning Companion', and 'Feeling'. In the process of relating the codes to each other and identifying the commonalities among the different open codes the 'She/Me Connection' and the 'Feeling' codes were grouped together because the utterances are related to the 'Connection' concept as featured in Table 9. Also, the 'Positive Reinforcement', 'Better Understanding' and the 'Better Performance' codes were coupled together because they are connected to the 'Learning Process' notion. Finally, the 'Feature of the System' and the 'Feature of the LC' codes were grouped together because they are related to the 'Teaching Features of MS'. The least predominant codes 'General,' 'Miscellaneous', 'Indifferent' and 'Not' were a small percentage of overall codes and their associated utterances do not provide detailed information so these codes were grouped together as N/A, see Table 9.

Table 9: Helpfulness of Companions - Axial and Selective Codes Based on Open Codes

'If you thought Jane was helpful, Why?'		
Open Codes	**Axial Codes**	**Selective Codes**
She/Me Connection; Feeling	Connection	Social Engagement
Positive Reinforcement; Better Understanding; Better Performance	Learning Process	Knowledge/Achievement
Feature of System; Feature of LC	Teaching Features	
General; Miscellaneous; Indifferent	N/A	N/A
Not	N/A	

For **Q2 – 'Describe your Learning Companion**', the most predominant open codes were: 'Physical Features', 'Gender', 'Evaluation', 'Personality', 'Like Me', 'Miscellaneous', 'Familiar' and finally 'Creative/Imaginative'. The process of axial coding includes relating the codes to each other and finding what the different open codes have in common. The 'Physical Features', 'Gender' and 'Creative/Imaginative' codes were grouped together because the utterances are related to the 'Appearance' concept as shown in Table 10. Also, the 'Evaluation' and 'Personality' codes were coupled together because they are connected to the 'Behavior' notion and the 'Like Me' and the 'Familiar' codes were connected together because they are associated to the 'Similar' concept, see Table 10.

Table 10: Description of Companions - Axial and Selective Codes Based on the Open Codes

'Describe your Learning Companion:'		
Open Codes	**Axial Codes**	**Selective Codes**
Physical Features; Gender; Creative/Imaginative	Appearance	Appealing

Evaluation; Personality	Conduct/Behavior	
Like Me; Familiar	Similar	Recognizable
Miscellaneous	N/A	N/A

Finally, for Q3-'Why did you design your Learning Companion the way you did?' the most predominant open codes were: 'Like Me', 'Gender', 'Creative', 'Cool', 'Familiar', 'Attractive', 'Diversity', 'Positive Reinforcement', 'Better Understanding' and 'Smart'. During axial coding, the process of relating the codes to each other and finding what the different open codes have in common. The 'Like Me', 'Familiar', 'Gender' and 'Diversity' codes were grouped together because the utterances are related to the 'Familiar/Culture' concept as displayed in Table 11. Also, the 'Creative, 'Cool' and 'Attractive' codes were grouped together because the utterances are related to the 'Personality' notion. Finally, the 'Positive Reinforcement' 'Better Understanding' and 'Smart' codes were grouped together because the utterances are related to the 'Scaffolding/Social Engagement' notion, see Table 11.

Table 11: Reason for Companion Design - Axial & Selective Codes Based on the Open Codes

'Why did you design your Learning Companion the way you did?'		
Open Codes	**Axial Codes**	**Selective Codes**
Like Me; Familiar	Familiar; Culture	Identity
Gender; Diversity		
Creative; Cool; Attractive	Personality	
Positive Reinforcement; Better Understanding; Smart	Scaffolding; Social Engagement	Knowledge/Achievement

Miscellaneous	N/A	N/A

QDA Image Analysis Protocol

Thematic image analysis was used to examine the student learning companion designs created with My Blue Robot. The My Blue Robot application features are displayed below in Table 12. Appendices E, F, and G show the My Blue Robot application eye, hair and skin color options. See Appendices E, F and G.

Image analysis was conducted to measure whether the student LC avatar design is similar or different to the image of the student. Images of the students were captured by the researcher or teacher and the student learning companion designs were compared to the student image for similarities and differences in order to understand emerging themes. The student designs were analyzed by eye color, hair color and skin color shade and then compared generally to students' actual eye, hair and skin colors. R1, the main researcher and author of this paper, quantitively analyzed the student designs solely by coding each student design along with a picture of each student. Eye color was assigned a 1 for brown, 2 for blue 3 for green and 4 for other. Hair and skin shade color was assigned a 1 for very light, 2 for light, 3 for medium 4 for dark and 5 for very dark and independent sample t-tests were performed.

Table 12: My Blue Robot Features

Feature	Colors	Shapes	Tools
Avatar		Blank male or female shape	Tools to move the avatar up, down & side-to-side; tool to increase/decrease

			avatar size; tool to tilt head
Face	20 skin color shade options plus color wheel too pick your own	15 face shape options	Tool to increase/decrease face shape size
Mouth	20 lip shade options plus color wheel to pick your own	15 lip shape options	Tool to move mouth up, down, side-to-side; tool to increase/decrease mouth/lip size
Nose	20 skin color shade options plus color wheel too pick your own	15 nose shape options	Tool to move nose up, down, side-to-side; tool to increase/decrease nose size
Ears	20 skin color shade options plus color wheel too pick your own	7 ear shape options	Tool to move ears up & down; tool to increase/decrease ear size
Eyes	20 eye outline color shade options plus color wheel too pick your own	18 eye shape options	Tools to move the eyes up & down and closer & farther apart; tool to increase/decrease eye size
Iris	20 iris color shade options plus color wheel to pick your own	10 iris shape options	Tool to move iris up, down, side-to-side; tool to increase/decrease iris size
Eyebrows	20 eyebrow color shade options plus color wheel too pick your own	15 eyebrow shape options	Tools to move the eyebrows up & down and closer & farther apart; tool to increase/decrease eyebrow size; tools to tilt and angle each eyebrow
Eyeglasses	20 eyeglass color options plus color wheel too pick your own	17 eyeglass shape options and a no glasses option	Tool to move eyeglasses up & down; tool to increase/decrease eyeglasses size

Hair	20 hair color shade options plus color wheel too pick your own	15 hair shape options and a no hair option
Clothes	20 shirt color options, no color wheel	18 shirt shape options
Backgrounds	20 background colors options plus color wheel too pick your own	14 background design options and a no background option

CHAPTER 5

RESULTS

This section will report the results of the data analysis of the Main study and will be organized by the descriptive results and then the qualitative results.

Quantitative Analysis and Results

The data analysis results from the main study survey are presented below in Table 14. The table includes questions about the students' perceived utility of the MathSpring pedagogical agent and about how students relate to the avatar/learning companion designs that they created. The quantitative results measure two constructs C1) 'Did the MathSpring Learning Companion help you learn? How?' and C2) 'How did you design your Learning Companion? Why?' These two constructs were confirmed by factor analysis (presented below) and measured on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree): do students find Jane, the MathSpring learning companion (LC) useful and are the features in the student created LC similar to students' features, see Table 14.

The overall scale consisted of six Likert items and Principal Components factor analysis confirmed that three of the survey Likert items mapped to the 'JaneHelpful' construct (C1) and three mapped to the 'AvatarLooksLikeMe' construct (C2) as featured in Table 13. Prior to analysis, items 2 and 6, 'Jane was not that useful to me, so I did not use her.' and 'The Learning Companion that I designed looks nothing like me.' were reverse coded.

In order to run the factor analysis, first, assumptions were tested. The Correlation Matrix showed many correlations greater than .3 which tentatively suggested that factor analysis is appropriate to run. Additionally, the Kaiser-Meyer-Olkin (KMO) Measure of Sampling was .728 which is above the recommended threshold of .6 and the Bartlett's Test of Sphericity reached statistical significance indicating the correlations were sufficiently large for factor analysis.

Next, two factors were extracted explaining 83% of the variance. This was decided based on eigenvalues and inspection of the scree plot. All factors with a Kaiser's eigenvalue greater than one were retained and the scree plot point of inflection fell at Factor 3 and suggested a two-dimensional scale. Factors were obliquely rotated using the Oblimin with Kaiser Normalization rotation and interpretation of the two factors was in keeping with the researcher's two-dimensional factor hypothesis. Each factor subscale comprised of three items and all items appeared to be worthy of retention. Items that loaded on the first dimension suggest that they represent the 'JaneHelpful' construct and explained 53.462% of the variance. Items that loaded onto the second dimension suggest that they represent the 'AvatarLooksLikeMe' construct and explained 29.607% of the variance, see Table 13.

Then, a Cronbach's alpha reliability score (α) was measured for the entire survey for all 76 respondents on all items and showed a good internal consistency to be (α=.82). After that, a reliability scale score was calculated for each dimension.

The three 'JaneHelpful' variables were combined to form a scale that measured the utility of Jane on all participants and produced an excellent internal consistency (α=.92). The 'AvartarLooksLikeMe' variables were also combined to form a subscale that measured whether the features in the student created LC are similar to students' features and produced a good internal consistency at (α=.87), see Table 14.

Table 13: Factor Analysis

	Loadings		
Items	**Factor 1** 'JaneHelpful'	**Factor 2** 'AvatarLooksLikeMe'	**Communality**
janeHelpedMe	.839	-.436	.893
janeHelpful	.762	-.542	.833
janeNotUseful_reverse	.746	-.525	.874
avatarNotLookLikeMe_reverse	.699	.582	.875
avatarHasMyCharacteristics	.665	.490	.827
avatarLooksLikeMe	.661	.662	.682
Eigenvalue	3.208	1.776	
% of Total Variance:	53.462	29.607	
Total Variance:		83.069%	

Finally, standard deviations and means were also determined for each subscale for all students, Hispanic, Caucasian, ELL and Non-ELL students and reported in Table 14. Additionally, the item statistics of the scale had a mean of 3.35 and the minimum was 2.96 while the maximum was 3.59 with a range of .632 and variance of .072. The Likert items that mapped to each subscale, as confirmed by factor analysis, are listed below and featured in Table 14.

C1 - 'JaneHelpful' subscale, 'Did the MathSpring Learning Companion help you learn? How?':

1. I liked using the Learning Companion, Jane, in MathSpring because she helped me understand.
2. Jane was not that useful to me, so I did not use her.
3. I think Jane was a very helpful part of MathSpring.

C2 - 'AvatarLooksLikeMe' subscale, 'How did you design your Learning Companion? Why?':

5. The Learning Companion/Avatar that I created looks a lot like me.
6. The Learning Companion that I designed looks nothing like me.
7. The Learning Companion that I created has a lot of my characteristics.

Table 14: Item Means and Standard Deviations

	Factor Subscales	**All** (*N*=76)	**Hispanic** (*N* = 61)	**Caucasian** (*N*= 15)	**ELL** (*N*=24)	**Non-ELL** (*N*=52)
	Mean (S.D.) [Alpha]	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)
I liked using the Learning Companion, Jane, in MathSpring because she helped me understand.	JaneHelpful 3.48 (1.14) [α = .92]	3.54 (1.14)	3.5 (1.12)	3.11 (1.19)	3.9 (.88)	3.2 (1.0)
Jane was not that useful to me, so I did not use her.		3.32 (1.31)				
I think Jane was a very helpful part of MathSpring.		3.59 (1.22)				

The Learning Companion/Avatar that I created looks a lot like me.	AvatarLooksLikeMe	3.12 (1.47)				
The Learning Companion that I designed looks nothing like me.	3.22 (1.23) [α = .87]	2.96 (1.50)	3.2 (1.14)	2.9 (1.57)	3.6 (1.0)	3.0 (1.2)
The Learning Companion that I created has a lot of my characteristics.		3.59 (1.16)				

These results are used to answer RQ2- 'Is the MathSpring LC helpful to Hispanic ELL students?' and RQ4 – 'Do the student designed LC avatars of Hispanic ELL students have similar characteristics and look like themselves?'.

RQ#2: Is the MathSpring LC helpful to Hispanic ELL students?

The results from the Main study quantitative analysis of construct1, C1 - 'JaneHelpful' are displayed in Table 14 and were used to answer, 'Do students find the MS pedagogical agent useful'. The survey questions that made up construct C1 were: 1) I liked using the Learning Companion, Jane, in MathSpring because she helped me understand; 2) Jane was not that useful to me, so I did not use her; and 3) I think Jane was a very helpful part of MathSpring. The results suggest that there is a difference between how helpful ELL students and non-ELL students find Jane the MathSpring LC.

An independent-samples t-test was conducted to compare whether there is a difference between how Hispanic students and Caucasian students find the MathSpring LC Jane helpful. There was not a significant difference between the scores for the Hispanic students (*M* = 3.5, *SD* = 1.12) and the Caucasian students (*M* = 3.11, *SD* = 1.19) conditions; t(74) = -1.4, p < .16. These results suggest that there is not a difference between how useful and helpful Hispanic and Caucasian students find Jane the MathSpring LC.

An independent-samples t-test was conducted to compare whether there is a difference exists between how ELL students and non-ELL students find the learning companion Jane in term of helpfulness. There was a significant difference between the ELL student (*M* = 3.9, *SD* = .88) and non-ELL student (*M* = 3.2, *SD* = 1.0) conditions; t(74) = -2.2, p < .028. These results suggest that there is a difference between how ELL students and non-ELL students find Jane the MathSpring learning companion in terms of usefulness and helpfulness.

RQ#4: Do the student designed LC avatars of Hispanic ELL students have similar characteristics and look like themselves?

The results from the Main study quantitative analysis of construct2, C2 - 'AvatarLooksLikeMe' are displayed in Table 14. The survey questions that were used to create the 'LooksLikeMe' subscale that measure the C2 construct, 'How did you design your Learning Companion? Why?', were: 1) The Learning Companion/Avatar that I created looks a lot like me; 2) The Learning Companion that I designed looks nothing like me; and 3) The Learning Companion that I created has a lot of my characteristics. The results suggest that the ELL students design their LC more similarly to themselves than the non-ELL students.

An independent-samples t-test was conducted to compare whether a difference exists between how similar the Hispanic students' and the Caucasian students' LC avatar designs are to themselves. There was not a significant difference between the scores for the Hispanic student (*M* = 3.2, *SD* = 1.14) and the Caucasian student (*M* = 2.9, *SD* = 1.57) conditions; $t(74) = -.937$, $p < .35$. These results suggest that the Hispanic students did not design their LC avatars more similarly to themselves then did Caucasian students.

An independent-samples t-test was conducted to compare whether a difference exits between how similar the ELL students' and the non-ELL students' LCs designs are to themselves. There was a significant difference between the scores for the ELL student (*M* = 3.6, *SD* = 1.0) and non-ELL student (*M* = 3.0, *SD* = 1.2) conditions; $t(74) = -2.0$, $p < .046$. These results suggest that the ELL students design their LC more similarly to themselves than do the non-ELL students.

Furthermore, the main study qualitative image analysis also supported the quantitative findings. ELL Learning companion avatar designs and images of students are displayed below in Table 16. Qualitative image analysis was conducted to measure whether the student LC avatar design is similar or different to the image of the student. The student designs were analyzed by eye color selected, hair color selected and skin color shade selected and then compared generally to students' actual eye, hair and skin colors. The scores for the student image analysis (StudentImage) were compared to the scores of student design images

(StudentDesign). StudentImage (*M* = 2.5, *SD* = .37) and StudentDesign (*M* = 2.4, *SD* = .623), see Table X.

An independent-samples t-test was conducted to compare whether a difference exists between the ELL students' and the non-ELL students' LCs designs. The t-test indicated that a difference exists between the ELL student and the non-ELL student conditions. There was a significant difference between the scores for the ELL student (M = 3.1 SD = .58) and non-ELL student (M = 2.8, SD = .47) conditions; $t(20) = 2.92$, $p < .008$. These results suggest that the ELL students designed their learning companions more similar to themselves than do the non-ELL students.

Of the twenty-four ELL students eighteen or seventy-five percent of students designed their learning companion/avatars with the same or similar color eyes as themselves. Also, seventeen or seventy-one percent of ELL students designed their learning companion/avatars with the same or similar hair color as themselves. Additionally, sixteen or sixty-seven percent of ELL students designed their learning companion/avatars with the same or similar skin shade color as themselves, see examples in Table 16. In contrast, of the fifty-two non-ELL students, only thirty-six or sixty-nine percent of students designed their learning companions with the same or similar eye color as themselves. Also, only thirty-four or sixty-five percent of non-ELL students designed their learning companion/avatars with the same or similar hair color as themselves. Additionally, only thirty-one or sixty percent of non-ELL students designed their learning companion/avatars with the same or similar skin shade color as themselves.

QDA – Case Study

The results from the analysis of the case study question CS_Q1: 'What do you think of the current learning companion in MathSpring? How does she sound? Look like?' were used to answer RQ1. To note, the main study participants were asked about how they perceive their avatar/learning companion design but not how they perceive Jane the existing MS APA.

RQ#1: How do Hispanic ELL students describe the design of how the MathSpring pedagogical agent looks, sounds and what they say?

The codes from CS_Q1 emerged into positive and negative themes. The positive codes associated with Jane the MS LC were; 'smart', 'supportive', 'helpful' and 'normal'. The negative codes associated with why students did not like Jane the MS LC were: 'boring', 'not noticeable' and 'not realistic'.

The positive codes associated with Jane the MS LC were; 'smart', 'supportive', 'helpful' and 'normal'. Examples of students' positive responses include: PCS_10 said: "I like when she speaks to me and tells me how good I'm doing", PCS_12 reported, "She is a good helper because when we finish your question and we get it right she says good job if we did a problem wrong she says try again", PCS_4 said: "she is supportive, if you get a question wrong she doesn't criticize you for it" and

PCS_6 said, “She looks like a normal person, she wasn’t computer-based she looked normal when she talked”.

The negative codes associated with why students did not like Jane the MS LC were: ‘boring’, ‘not noticeable’ and ‘not realistic’. Students who felt that Jane has a boring style said; “she has a boring style and she is not noticeable and realistic enough”, “she is really a plain Jane”, “she has no enthusiasm or like an accent she has no flavor” “She should have more style” and “she needs more character to her”. Students who thought that she was not noticeable said, “she is in the corner, I didn't really notice her”, “she is too mellow” and “she should be more enthusiastic and she might ask “do you need help” or if you need assistance” and finally “she doesn't move she just sits there”. Students who felt that she should be more realistic said: “she should sound less like a robot and be more realistic looking”, “she should have a more normal voice” and “she sounds corny”.

QDA - Main Study - Selective Coding Analysis

Following the Grounded Theory QDA selective coding a model of the emerging narrative based on the interrelationships of the categories is presented with analysis for each question. Then each question is discussed further in relation to the previously presented figured worlds theoretical framework in the Chapter 6, Discussion. Selective coding was conducted to choose core categories that relate to other categories. Hypotheses about the interrelationships of the core categories were formed to thread a storyline around which everything else was draped.

The model of the emerging narrative based on the interrelationships of the core categories of **Q1- 'If you thought Jane was helpful, Why'** is presented in Figure 4. During Selective coding, the 'She/Me Connection' and the 'Feeling' Axial codes were combined into a 'Social Engagement' category and the 'Teaching Features' and 'Learning Process' Axial codes were combined into an overall 'Knowledge' category. 'Social Engagement' and 'Knowledge' were the prominent themes that arose for Q1 during Selective coding. Using the themes of 'Social Engagement' and 'Knowledge' to weave a storyline around 'Why Jane is Helpful' it is apparent that students feel that the social engagement that is provided by Jane provides a sense of connection that contributes to learning and making knowledge with Jane and the MathSpring system.

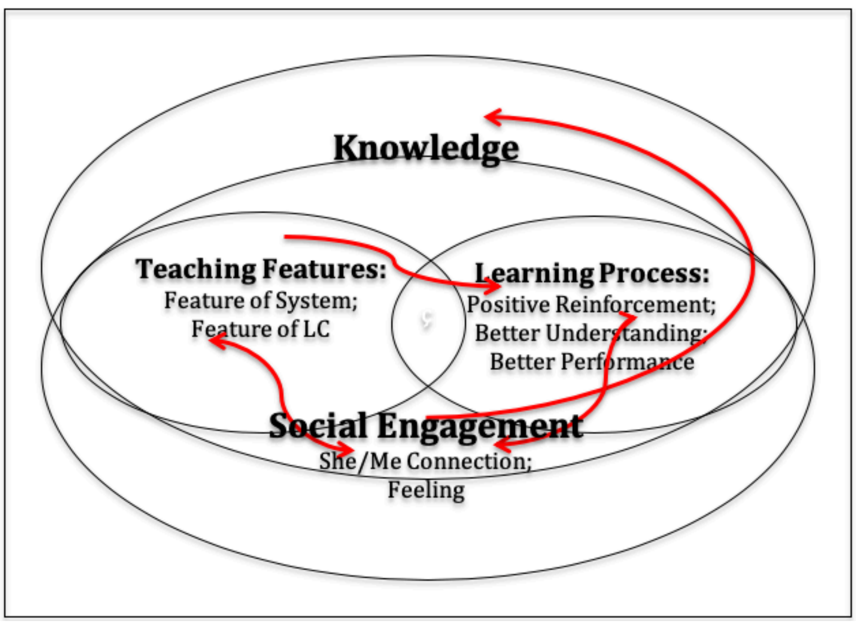


Figure 4: Q1 Narrative Model of core categories of why students thought Jane was helpful

The 'She/Me Connection' is a core concept is behind the students' responses to Q1. For example, PCA_13 said: "She encouraged me to keep trying the math." and PCA_4 reported, "he helped me learn new things and got me better grades". While PNE_36 expressed, "Jane was helpful because she encouraged me to do better and to help me learn better she also read the question for me." and PCA_12 also said, "I thought Jane was helpful because when Jane said good job it makes me feel good that I did it." Additionally, PNE_22 said, "She made feel confedent [*sic*]." and PCA_22 reported, "She made me fell [*sic*] that I'm not alone learning, and she mad [*sic*] me fell [*sic*] confident.".

The overall story of the core categories is: the motivating and scaffolding 'Teaching Features' of the LC and system contribute to the 'Learning Process' by providing positive reinforcement, better understanding and performance. These features also create a 'Connection' with Jane that makes the student feel confident and helps them succeed to learn and make 'Knowledge', see Q1 Model, Figure 4.

These findings are used to answer RQ3 – 'What aspects of the MathSpring LC do Hispanic ELL students find helpful and in what ways?

RQ#3: What aspects of the MathSpring LC do Hispanic ELL students find helpful and in what ways?

Findings from both the case and main studies were used to answer, 'What aspects of the MathSpring LC do Hispanic ELL students find helpful and in what ways?'. The findings from the analysis of the qualitative case study question, CS_Q9 –

‘What should your learning companion do? How can your learning companion help you learn Math?’ were used to answer RQ#3. Additionally, the findings from the main study qualitative Q1 Narrative Model that was based on the analysis of the open response question Q1 ‘Why was Jane Helpful’ were also used.

The main themes from the case study qualitative results of the students’ responses to CS_Q9: ‘What should your learning companion do? How can your learning companion help you learn Math?’ were that the learning companion should provide scaffolding for learning and interaction. Students who thought that the learning companion should provide scaffolding for learning. PCS_11 said: “She can give pointers to help you understand the different options on how to learn” and PCS_9 expressed that “she should give you helpful tips on how to improve the math skills”. Students thought that the learning companion should be more interactive and PCS_3 said: “she should give rewards like points so that that you can buy plants for the garden and have a plant for each topic”, PCS_10 reported, “she should be interactive and move and use gestures” and PCS_2 said, “The avatar should move and use gestures. She should walk out and use her hands and to point to examples”.

Additionally, the storyline from the Q1 Narrative Model indicate that the motivating and scaffolding ‘Teaching Features’ of the LC and system contribute to the ‘Learning Process’ by providing positive reinforcement, better understanding and performance. The features also create a ‘Connection’ with Jane that makes me feel confident and helps me succeed to learn and make ‘Knowledge’, see Q1 Model, Figure 4.

Table 15: Helpfulness of Jane: Qualitative Open-Ended Survey Results from ELL Students

If you thought Jane was helpful, Why?

Participant	Utterance
PCA_26	“I thought Jane was helpful because she encouraged me and she helped me out. She also, congratulated me when I got something correct.”
PNE_20	“She was help full because so showed you examples of your problem. That helped do your problem.”
PNE_16	"She was helpful because she gave us hints"
PCA_13	“Jane was helpful because she encouraged me to do better and to help me learn better she also read the question for me.”
PNE_34	“I thought she was helpful because she is smart.”
PNE_39	“She was helpful due to me not knowing a decimal problem she gave me an example.”
PNE_12	“She explained what to do when i needed help and it was helpful”
PNE_21	“she gave hints if you were struggling”
PNE_37	“Because she was nice explained everything you did not understand”
PCA_14	“Jane was helpful because she gives us some good advice. And tells us math can be very challenging.”
PCA_15	“Jane was helpful because she told us how to do the math problem.”
PCA_25	“he or she gave us good advice about how good we were doing.”
PCA_30	“I think she was helpful because if I finished the problem she says good job and great job and i think that encourages me.”
PCA_32	“Because she was giving me exampeles [*sic*] of what the question is going to be like. Also because I was kinda getting some of the answers right. And she gave me hints on what to do.”
PCA_33	“because when i pectic an answer she told me she did not now that one.”
PCA_34	“She helped me learn that there was hints videos and other things.”
PCA_35	“I think jane was help full because [*sic*] it gave u motivation.”

The model of the emerging narrative based on the interrelationships of the core categories of **Q2-’Describe your Learning Companion.’** is presented in Figure 5. During Selective coding, the ‘Appearance’ and ‘Conduct/Behavior’ Axial codes were combined into an ‘Appealing’ category and the ‘Similar’ Axial code was maintained. ‘Appealing’ and ‘Similar’ were the prominent themes that arose for Q2 during Selective coding. Using the ‘Appealing’ and ‘Similar’ themes to weave a storyline around 'Describe your Learning Companion' it is apparent that *students designed their learning companion avatars to be attractive and recognizable*. The 'Like Me/Familiar' concept is the main force behind the students' responses.

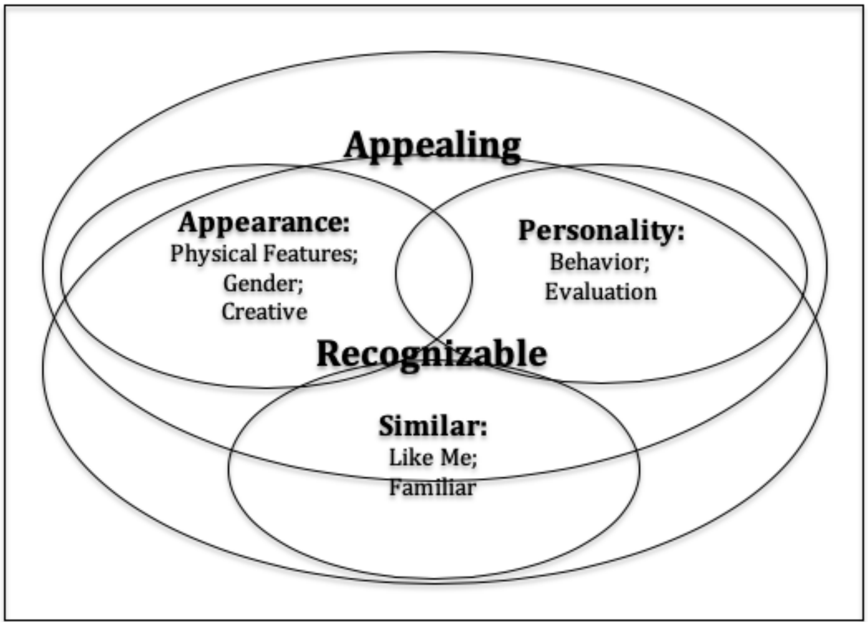


Figure 5: Q2 - Narrative Model of core categories of how students described their learning companion designs

The overall story of the core categories is: students designed the physical features and behaviors of their learning companions to be familiar and like themselves to create an 'Appearance' and 'Personality' that is 'Recognizable' and 'Appealing', see the Q2 Model, Figure 5. These findings are used to answer RQ5 – 'How do Hispanic ELL students describe their student created learning companion designs and how do they explain their design choices?'. The analysis of RQ5 comes after the following Q3 narrative model breakdown.

The model of the emerging narrative based on the interrelationships of the core categories of **Q3-'Why did you design your Learning Companion the way**

you did?' is presented in Figure 6. During Selective coding, the 'Familiar' and the 'Culture' and 'Personality' Axial codes were combined into a 'Identity' category and the 'Scaffolding' and 'Social Engagement' Axial codes were combined into an overall 'Knowledge' category. 'Identity' and 'Knowledge' were the prominent themes that arose for Q3 during Selective coding. Using the themes of 'Identity' and 'Knowledge' to weave a storyline around 'Why did you design your learning companion the way you did?' it is apparent that students designed their learning companion avatar so that they could identify and learn from them. 'Like Me/Familiar' is a core concept behind the students' responses to Q3. For example, PNE_10 said, "I designed it like this because she looks like me, a student that loves to help and learn math.". PCA_31 also expressed that, "I designed my Learning Companion the way I did because she looks like me and I'm used to how I look so the only way I thought I could design it with my features.". Additionally, PCA_16 said: "I wanted him to look like me and I will make him have all my personalities and my characterisics [*sic*]."

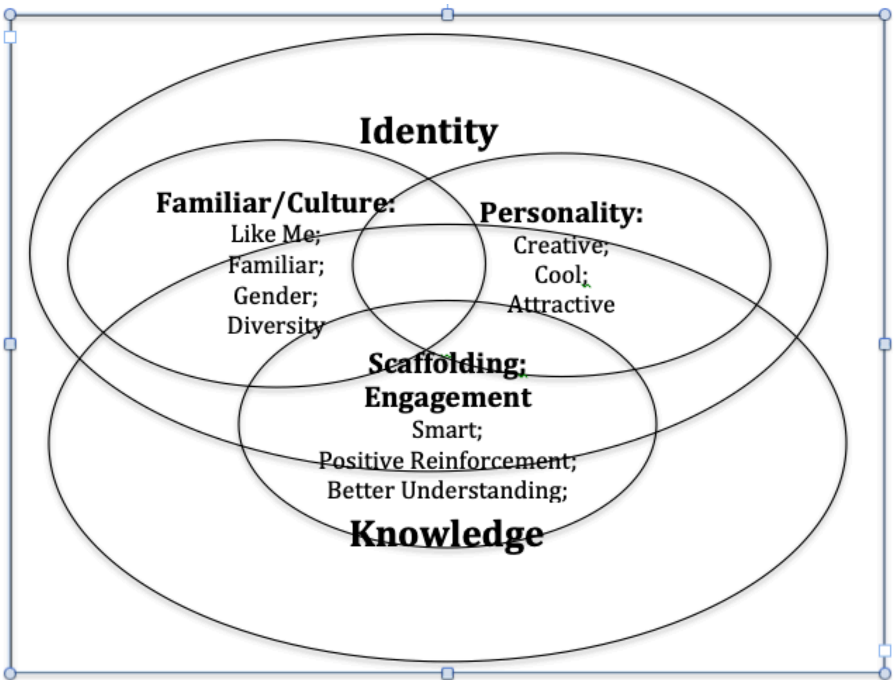


Figure 6: Q3 Narrative Model of core categories of why students made their learning companion design choices

The overall story of the core categories is: students designed diverse, familiar and attractive learning companions that were engaging and helpful. They designed their learning companions to be 'Familiar' in terms of gender and culture with attractive 'Personalities' that provide 'Social Engagement' and 'Scaffolding' with positive reinforcement and better understanding, see the Q3 Model, Figure 6. These findings along with the findings from the Q2 model are used to answer RQ5 – 'How do Hispanic ELL students describe their student created learning companion designs and how do they explain their design choices?'.

RQ#5: How do Hispanic ELL students describe their learning companion designs and why they made their design choices?

Results from both the case and main studies were used to answer, 'How do Hispanic ELL students describe their learning companion designs and why they made their design choices?'. The results from the analysis of the following qualitative case study questions were used to answer RQ5, CS_Q5: 'What can you tell me about the avatar/learning companion that you designed (age, gender, race, ethnicity, clothes and hairstyle)?', CS_Q7: 'What should your learning companion sound like?' and CS_Q8: 'What should your learning companion say?' Additionally, the findings from the main study qualitative Q2 and Q3 Narrative Models based on the analysis of the open response questions Q2 (describe your avatar/learning companion) and Q3 (why did you design it that way) were also used.

Case Study Analysis

The main themes from the case study analysis of the students' responses to CS_Q5: 'What can you tell me about the avatar/learning companion that you designed (age, gender, race, ethnicity, clothes and hairstyle)?' were that she is **relatable and reflection of the participant** and looks like the participant. Students indicated that their learning companion is **relatable**. PCS_3 said: "Well she kind of looks like me because of her light eyes and her hair is straightened. I put her my skin color and obviously I'm not white. She can relate to people like us because she had straightened hair like some white people and she has my skin color and light eyes. She is a mix and can relate to many people.". PCS_2 also said: "The person would be like 24 to 38 age person because that is young, not to be insulting or anything but you know sometimes the older teachers don't get us and are not as relatable, younger teachers are better. I assume she's Hispanic." Additionally, PCS_6 said: "She is 13 but everybody thinks that she is older. Her race is African American and a little bit of Caribbean. Her clothes she has a little flared back top to make it seem like she doesn't have to be a girl she could wear boys clothes. That is why I chose the open front shirt, that is non-gender conforming. I wanted to do something where anybody could relate, they don't have to have the clothes of a girl or of a boy to symbolize their gender."

Many students also expressed that their learning companion is a **reflection of themselves** and/or looks like them. PCS_5 said, "I designed a white avatar I tried to copy me almost but too much, I changed the eyes to blue and her skin is a little bit more pale than mine and her hair is darker. I pick this combination because it is not as common to have blue eyes and dark hair. She is a mix.". PCS_1 also said, "I made her kind of like me because I'm really exciting and I like to joke. She's 13, she's Puerto Rican and Black. She doesn't have just one culture because she's mixed.". Additionally, PCS_10 described that "She is 14 she's a Christian and Catholic. Her hair is black and she has bangs that are not too neat. I'm not done yet I want to try to make her feel how we feel. Like something that could reflect off of us and be the way she's feeling. I want her to reflect the emotions of how we are feeling. then when somebody walks by they can tell how I am feeling by looking at her. She is a reflection of me."

Next, the main themes from the case study analysis of the students' responses to CS_Q7: 'What should your learning companion sound like' were that the learning companion should **sound familiar and be encouraging**. Students felt that the learning companion should **sound familiar**. PCS_5 said: "She should ask if you need help or if you're having issues. She would have an accent that is a mix of everybody's, but it is clear." PCS_6 also expressed that, "I feel she should sound mellow and sound natural, not operated. Someone you can relate to or talk to so when you can look at in the game and go like oh my God I can relate to her or if she's so fashionable and cool." Additionally, PCS_10 said: "She should sound like me - nice, complimentative. Students also felt that the learning companion should sound **encouraging** and provide positive reinforcement. PCS_11 said the LC should sound, "Positive, helps others." PCS_9 also reported, "She should have a positive attitude and encourage them to keep learning even if they get something wrong." Additionally, PCS_1 expressed, "She should sound exciting and encouraging." Finally, PCS_3 expressed, "Encouraging, keep going and try your best. Math can sometimes get boring after a while if your teacher doesn't keep you interested in it and gives fun activities and rewards."

Finally, the main themes from the case study analysis of the students' responses to CS_Q8: 'What should your learning companion say?' were that the learning companion should say things to **help scaffold learning and to be more interactive**. Students felt that the learning companion should **scaffold learning** and PCS_11 said, “Give hints, no answers, just help.” PCS_9 also noted, “It’s okay if you get one question wrong because we’ll show you what you did wrong and how to get the right answer for the next problem.” Additionally, PCS_3 expressed that the LC should, “Explain the math step.” Furthermore, PCS_2 said, “Well instead of saying wow, you were excellent, I think if you get something wrong the companion should pop up into the center of the screen instead of on the side and she can talk to you and help you understand why you got your problem wrong.” Finally, PCS_6 said the LC should “Ask if you need help.”

Students who thought that the learning companion should be more **interactive** and_PCS_1 said, “She should say jokes.” PCS_2 also noted, “sometimes she could go to the side and gesture by using her hands to point to examples on the side of her.” Additionally, PCS_10 expressed that, “She should be interactive. When somebody walks by she should say hi, She should compliment [*sic*] somebody when they walk by about what they are wearing.”

Main Study Q2 Narrative Model Analysis

The findings from the main study qualitative Q2 Narrative Model that was based on the analysis of the open response question Q2 ‘Describe your Learning Companion.’ indicate that students designed the physical features and behaviors of their learning companions to be familiar and like themselves to create an

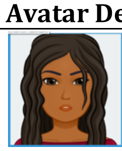
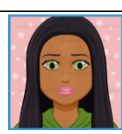
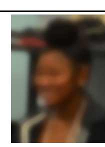
‘Appearance’ and ‘Personality’ that is ‘Recognizable’ and ‘Appealing’, see the Q2 Model, Figure 5.

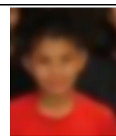
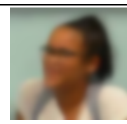
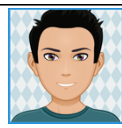
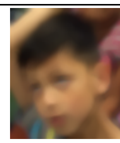
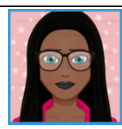
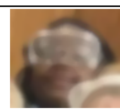
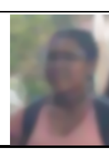
Main Study Q3 Narrative Model Analysis

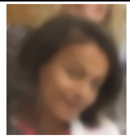
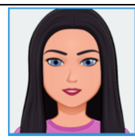
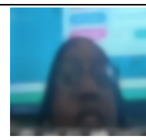
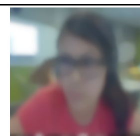
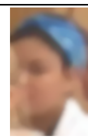
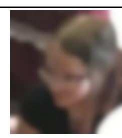
Additionally, the findings from the main study qualitative Q3 Narrative Model that was based on the analysis of the open response question Q3 ‘Why did you design your Learning Companion the way you did?’ indicate that students designed diverse, familiar and attractive learning companions that were engaging and helpful. They designed their learning companions to be ‘Familiar’ in terms of gender and culture with attractive ‘Personalities’ that provide ‘Social Engagement’ and ‘Scaffolding’ with positive reinforcement and better understanding, see the Q3 Model, Figure 6.

ELL learning companion avatar designs and images of the students along with the students’ descriptions of their learning companions and why they designed their LCs the way they did are displayed below in Table 16.

Table 16: ELL Student Created LC Avatar Designs, Images and Descriptions

Participant	Student LC Avatar Design	Student Image	Student Description	Why design
PCA_18			“My learning companion has brown hair and brown eyes.”	“I designed my learning companion the way I did because I wanted her to look smart and like she knew what she was doing.”
PNE_7			‘Well she kind of looks like me because of her light eyes and her hair is straightened. I put her my skin color and obviously I’m not white. She can relate to people like us because she had	“She is a mix and can relate to many people.”

			straightened hair like some white people and she has my skin color and light eyes.”	
PCA_19			“My learning companion is very helpful i like that have that.”	“I design my learning companion to look like me because i don't like designing thins that don't look like me.So that's is why i did mine like the way i did it.”
PNE_3			“I made her kind of like me because I’m really exciting and I like to joke. She’s 13, she’s Puerto Rican and Black. She doesn’t have just one culture because she’s mixed.”	“My avatar is just like me.”
PCA_5			“happy but shy in home gets crazy but in school no.”	“I designed my avatar the way i did because he looked a lot like me and he also looks cool.”
PNE_8			“She is 13 but everybody thinks that she is older. Her race is African American and a little bit of Caribbean. Her clothes she has a little flared back top to make it seem like she doesn’t have to be a girl she could wear boys clothes.“	“She looks like me, I made her similar to me so that I can relate to her. I can see myself I feel like I can change whatever I want. There's not one look I have to have. I can change it to whatever I want to whenever I feel symbolizes myself. I chose the open front, shirt that is non-gender conforming, I wanted to do something where somebody could relate, they don’t have to have the clothes of a girl or of a boy to symbolize their gender.”
PNE_37			“nice”	“because they resembled hope black girl magic.”

PNE_17			"I would describe and make it as a funny, nice, and pretty puerto rican woman with dark hair. and eyes like me."	"I designed my learning companion the way I did because I am so used to people saying puerto ricans alway cause trouble and are always not smart even though we can be."
PCA_9			"My learning avatar has fair skin and black hair as well as full eyebrows."	"I designed it that way because a lot of people look that way."
PNE_30			"She is mid toned. She has flowing mid brown hair with bold light lilac eyes. Shes in a causal t."	"I wanted my character to have many aspect. I wanted my avatar to be bold and different yet have the friendly aspect about her. So shes not so generic you get annoyed with her. Yet shes relatable in a sense."
PNE_5			"I tried to copy me almost but not too much, I changed the eyes to blue and her skin is a little bit more pale than mine and her hair is darker."	"I pick this combination because it is not as common to have blue eyes and dark hair."
PNE_12			"The person would be like 24 to 38 age person because that is young, not to be insulting or anything but you know sometimes the older teachers don't get us and are not as relatable, younger teachers are better. I assume she's Hispanic."	"Younger, like I am. Closer to my age. I made her similar to me because that seems familiar. Some people, well not to be rude or anything but a lot of the times the avatars are usually like white ladies and they are talking and people are like I don't like that because it's like all over the place. Some people like changing it other people don't like changing it and you can randomize it. When you're picking a shirt in your mind you can be

	thinking about what kind of person it's going to be, is this going to be like a cool person."

CHAPTER 6

DISCUSSION

The purpose of this mixed-methods study was to investigate how Hispanic and English Language Learners (ELL) students perceived the usefulness of the MathSpring (MS) animated pedagogical agent (APA) and how they relate to student created learning companion designs. This chapter first presents a summary of the results followed by an interpretation of the results in relation to the figured worlds (FWs) identity theoretical framework presented in Chapter Two*.* Then implications are reported and succeeded by ethical considerations. Next, limitations of this study and recommendations for future research are presented. Finally, conclusions are given.

Summary of Results

This research analyzed how Hispanic ELL students perceived the utility of and related to an avatar design in the context of Holland et al.'s FWs identity theory framework (1998). Based on the social and cultural Identity framework of the FWs Theory by Holland et al., the researcher hypothesized that the more a learner socially engages with their animated pedagogical agent (APAs) the more likely he or she is to form a FW (that has the power to shape the student's senses of themselves as learners of math) and be immersed in the intelligent learning environment (ILE) and to have a favorable or satisfactory experience.

Mixed-methods data was collected from 76 middle school students interacting with the MathSpring (MS) math tutor and the findings were triangulated among quantitative measures, open-ended survey responses and learning companion (LC) design images. The results indicate that ELL students find the MathSpring LC more useful and helpful than do non-ELL students and the ELL students designed LCs that looked more like themselves than did the non-ELL students. The overall findings suggest the more the learner identifies and engages with the APA the more likely he or she is to be immersed in the ILE, and to have a favorable or satisfactory experience.

Interpretation of Results

The quantitative results used to answer **RQ#2: 'Is the MathSpring LC helpful to Hispanic ELL students?'**, indicated that ELL students find the MathSpring LC more useful and helpful than do non-ELL students. The results that ELLs find APAs helpful are in line with the claims of Botes & Mji (2010) that students who used a researcher developed learning companion that would assist learners to relate mathematics terms and concepts in English with terms in their own languages had an improved performance in learning mathematics.

The quantitative results, that were used to answer **RQ#4: 'Do the student designed LC avatars of Hispanic ELL students have similar characteristics and look like themselves?'**, indicated the ELL students designed LCs that looked more like themselves than did the non-ELL students. These results are in line with the claims of Kim et al., (2007) that high school students chose to work with a peer-like agent over a teacher-like agent and also with (Kim & Wei, 2011; Moreno & Flowerday, 2006; Plant et al., 2009) who claim that students preferred to work with an agent with the same ethnicity more than with a different ethnicity.

Interpretation in Relation to FWs Identity Theory

Interactive learning environments (ILEs), particularly those embedded with APAs, are rich and complex spaces where students can construct and negotiate positive learner identities. This identity work occurs within Figured Worlds (FWs) where people are constantly developing and acting out self-understandings. When the three narrative models (Q1, Q2, and Q3) are related to the FWs framework, two FWs emerge that were important to the participants. This section is organized by the FWs that emerge from the models and how they address the RQs.

The predominant FWs that emerge from the Q1-Q3 models based on students' interactions with the learning companion are the 'SheLooksLikeMe' (identity) (**FW_I**) and the 'SheHelpsMe' (learn) (**FW_L**) figured worlds.

Q1: Figured Worlds of Learning

FWs that emerged from the Q1 narrative model were used to tie the data to the theory and helped to answer **RQ#3: 'What aspects of the MathSpring LC do Hispanic ELL students find helpful and in what ways?'**. The Q1 'Why was Jane Helpful' FW of learning is SheHelpsMeLearn'. In the Q1 FW of ''Why was Jane Helpful' (**FW_L**) the students felt that Jane was helpful because of their connection to her and because she scaffolded learning and provided encouragement through social engagement.

The Q1 'JaneIsHelpfulBecause' FWs of learning are 1) the 'SheHelpsMeLearn' (social engagement) in the form of Jane as *tutor* (provides scaffolding) and the student as a learner (with better understanding and performance) (and 2) the 'SheHelpsMeLearn' (social engagement) in the form of Jane as *motivator* (provides positive reinforcement and encouragement) and the student as a (confident) learner.

In the figured worlds of learning (**FW_L**) the student socially engages with Jane, the MS APA. Students enter the figured world of learning by logging into the interactive learning environment of the MathSpring intelligent tutoring system (ITS) and socially engage with an ITS artifact, the animated pedagogical agent, Jane. FW#1 is socially produced between the student and the MS APA, Jane, and is created via an interpreted ideal realm of the students' imagination. In this FW, certain APA acts such as encouraging and scaffolding are valued by the student and certain actors are valued and contribute to power structures. Jane is the encouraging tutor and the student is the learner because Jane has the power in the form of knowledge/hints. In this FW better performance learning comes are valued. In FW#1, Jane has knowledge, she encourages and scaffolds learning with hints. She connects to the learner and contributes to learner confidence, understanding and better performance.

The first, specific FW of learning (**FW_L1**) is one of Jane as the *tutor* (provides scaffolding) and student as a learner (with better understanding and performance). The second, specific FW of learning (**FW_L2**) is one of Jane as the *motivator* (provides positive reinforcement and encouragement) and the student as a (confident) learner. The findings indicate that when students engage with Jane, the MS APA, they feel connected to her and she helps them learn.

Q2: Figured World of Identity

Figured Worlds that emerged from the Q2 and Q3 narrative models were used to tie the data to the theory and helped answer **<u>RQ#5: 'How do Hispanic ELL students describe their learning companion designs and why did they make their design choices?'</u>**. The Q2 'Describe your learning companion design' FW of identity is 'SheLooksLikeMe'. In the Q2 FW of 'She is Like Me' (**FW_I**) the student feels that the LC represents them, including their diverse gender and culture representation.

The FW of identity (**FW_I**) is one with the student and their LC design. Students enter the FW of identity by creating their own LC designs and ITS artifacts with the MyBlueRobot application. **FW_I** is socially produced and culturally constructed between the student and their LC design, and is created via an interpreted ideal realm of the students' imagination. In this FW, certain features of the student created LC designs such as ethnicity, gender identity and age are valued by the student. In this FW, both the actors (the student and their LC) are valued and contribute to a power structure. The power structure seems to even out when the APA is a reflection of the students supporting students to identify with and relate to the LC. This connection seems to lessen the hierarchical power structure and afford a better learning environment. In this FW relatable connection outcomes are valued – when the student learning companion design features reflect the gender, ethnicity and age of the student, the student finds the LC familiar and relatable and is able to identify and connects with it. In the FW_I**,** the student designed LC is a reflection of the students' ethnicity, gender and age and allows the student to identify with and relate and connect to the LC.

The general FW of identity (**FW_I**) is one where the student's learning companion avatar reflects the student's gender, ethnicity and age. The findings indicate that in order for students to identify with their LC and achieve an intersubjective 'SheLooksLikeMe' state they design their LCs with familiar gender and familiar physical features and personality traits.

Q3: Figured Worlds of Identity and Learning

The Q3 'Why did you design your learning companion the way you did' FWs of identity and learning are 1) 'SheLooksLikeMe' (identity), 2) the SheHelpsMeLearn' (social engagement) in the form of Jane as tutor (provides scaffolding) and student as learner (with better understanding and performance) and 3) the 'SheHelpsMelearn' (social engagement) in the form of Jane as motivator (provides positive reinforcement and encouragement) and student as (confident) learner.

The FWs of identity (SheLooksLikeMe) and learning (SheHelpsMeLearn) are composed of the student and the LC. Students enter the FW_I by creating their own LC designs and ITS artifacts with the MyBlueRobot application. FW_L is socially produced and culturally constructed between the student and their LC design, and is created via an interpreted ideal realm of the students' imagination. In this FW, certain identity features of the student created LC designs such as ethnicity, gender identity and age are valued by the student. Other APA acts that contribute to learning such as encouraging and scaffolding are also valued by the student. In this FW, both the actors (the student and their LC) are valued and contribute to power structure. Jane is the encouraging tutor and the student is the learner because Jane has the power in the form of knowledge/hints. The power structure in this figured world seems to less hierarchical because the LC is a reflection of the students which allows students to identify with and relate to the LC. This connection lessens the hierarchical power structure and seems to afford a better learning environment. In this FW, both relatable connections and better performance learning outcomes are valued. When the student learning companion design features are a reflection of the gender, ethnicity and age of a student, the student finds the LC familiar and relatable and is able to identify and connect with it. Additionally, in this FW the LC has knowledge; encourages and scaffolds learning while connecting to the learner and contributes to learner confidence, understanding and better performance.

The general FW of identity (**FW_I**) is one where the learning companion avatar reflects the student's gender, ethnicity and age. The first, specific FW of learning (**FW_L1**) is one of Jane as the tutor (provides scaffolding) and student as a learner (with better understanding and performance). The second, specific FW of learning (**FW_L2**) is one of Jane as the motivator (provides positive reinforcement and encouragement) and the student as a (confident) learner. The findings indicate that students design their LC for both familiarity/identity and learning. In order for students to identify with their LC and achieve an identity construction 'SheLooksLikeMe' state they design their LCs with familiar gender and culturally diverse physical features and personality traits. Additionally, when students engage with their LC, they feel connected to her and she helps them learn.

Implications

Chapter III included descriptions of several identity theory concepts in relation to FWs. The concepts of inter-subjectivity, identity construction, social engagement, culture and lastly, communication, culture, and APAs were reviewed in relation to FWs. How the FWs of learning discovered in this study fit with these concepts is discussed in this section. Implications of this study for ELLs using math ITSs that feature APAs are also discussed.

In the figured world of learning (**FW_L**), Jane has knowledge, she encourages and scaffolds learning with hints. She connects to the learner and contributes to learner confidence, understanding and better performance.

The first, specific 'SheHelpsMeLearn' FW of learning (FW_L1) is one of the learning companion as a *tutor* (provides scaffolding) and student as learner (with better understanding and performance). FW_L1 is socially produced between the student and the MS APA, Jane and students felt that Jane was helpful and they had better performance because she scaffolded learning with hints through social engagement. The second, specific 'SheHelpsMeLearn' FW of learning (FW_L2) is one of the companion as *motivator* (provides positive reinforcement and encouragement) and the student as a (confident) learner. FW_L2 is also socially produced between the student and the MS APA, Jane and students felt that Jane was helpful and they had better confidence because she provided encouragement through social engagement. The following identity concepts are connected to the figured worlds of learning (FW_L). The concept of **inter-subjectivity** explains how interacting with an animated pedagogical agent (APA) may evoke a sense of inter-subjectivity (sharing of subjective state) for some students. This intersubjective connection encourages students to respond to their animated LCs in fundamentally social ways. **Social engagement** is a framework for technology-based teaching that explains how learning occurs when students are meaningfully engaged in activities through interaction with others and worthwhile tasks.

The general FW of 'SheLooksLikeMe' (**FW_I**) is one where the student's learning companion avatar represents the student's gender, ethnicity and age. In the FW_I**,** the student designed LC is a reflection of the students' ethnicity, gender and age and allows the student to identify with and relate and connect to the LC.

The following identity concepts are connected to the figured worlds of identity (FW_I). The concept **Identity Construction** happens in ITSs that feature APAs that allow students to design their learning companions with features that reflect the gender, ethnicity and age of the student. This may allow the student to find the LC familiar and relatable and able to identify and connect with it. The **Culture and Communication** framework elucidates that communication styles (appearance, gesturing, reasoning style, verbal and non-verbal communication, feel and display of emotions) is one of the main aspects of behavior that is influenced by culture. FWs of cultural identity are formed and the agent is often perceived as more believable, relatable and trustworthy by the user when APA is designed consistently sensitive to cultural norms, values and beliefs.

ELLs Co-designing APAs

Implications of this study for ELLs using math ITSs that feature APAs are that ELL students should be given time to design their own learning companions. APAs afford user representation and systems should be designed to allow learners interactive control features that enable them to help co-design, customize and produce their learning environment and experience by designing their own learning companions. This may result in learners experiencing a sense of presence that may afford engagement and collaborative learning (Dede, 2003; Dickey, 2003). When students become active producers, their actions co-create their learning activity, the world they are in, and the experiences they have (Gee, 2007). Co-designing means ownership, buy in and engaged participation. It is a key part of motivation (Gee).

Interactive ITS system features that include manipulation/customizability of user representation allow for adaptability which affords opportunities for identity construction, role-playing, multiple perspectives, and activity customization (Bers, 2001; Dede, 2009; Dickey, 2003; Gee, 2004; Mimirinis, 2007). These features result in learner experiences of the sense of presence and identity construction and afford constructivist experiential, situational and collaborative engagement and learning opportunities that allow for the creation of mental maps and development of internal schema that may contribute to deep learning and positive learning outcomes. (Jonassen, 2003; Novak & Cañas, 2008; Mimirinis, 2007).

Identity creation allows for learners to be situated in authentic experiences affording opportunities to be engaged in communities of practice focused on ‘medicine, ‘research’ or ‘science’ and to learn by doing producing meaningful experiences. Deep learning can be accomplished when people take on an identity they value and in which they become heavily invested (Annetta, 2008; Bers, 2001; Mimirinis, 2007). Student virtual identities can trigger deep investment and allow for students to project their own desires, and traits onto their avatar (Annetta).

According to Mimirinis the more involved and interactive a student is with his or her learning environment through manipulation, the deeper the student investment in learning is.

The visual representation of virtual avatars makes users feel that they are actually present in the virtual environment (Nowak & Biocca, 2003; Barab). In recent research the sense of presence contributing to a unique sense of engagement has been identified as one of the crucial factors for learning success (Annetta, 2009; Herrington, Oliver & Reeves, 2003; Mikropoulos). Thus, ITSs that feature customizable APAs have great potential for engaging students and achieving learning success.

Ethical Considerations

This study focused on a vulnerable population of learners, math students. Furthermore, the subjects were primarily female, Hispanic ELL math learners. A main purpose of this study was to give these students a voice to allow them to express their truth and values providing them with dignity in relation to identity. Participants were treated with respect and great measures were taken to make sure that their privacy, well- being and safety was not compromised.

Limitations

One primary limitation of this study was the small number of students evaluated. Seventy-six middle school students were evaluated. If the sample size of this study was larger the power of the study would increase power and the margin of error would be reduced. The generalizability of the results is limited by the smallish sample size.

Also, this study was conducted in classrooms with primarily Hispanic students. The number of Caucasian students was very small and there is interest in continuing this work with a future study that includes more Caucasian students in order to further explore whether there is a difference between how Hispanic ELL students relate to the MathSpring LC and their LC designs compared to Caucasian English-speaking students.

Additionally, students' technology usage outside of the classroom was not surveyed and therefore there may have been differences in usage that would have led to differences in how students interacted with the technology.

Finally, the RQ#1: 'How do Hispanic ELL students describe the design of how the MathSpring pedagogical agent looks, sounds and what they say?' is a limitation. Only the Case study participants were asked this question. The Main study participants were not asked about the design of Jane, they were only asked if they found Jane helpful and why.

Recommendations for Future Research

Many research issues remain to be addressed in the area of role of animated companions in ILEs. For example, research is needed to examine whether previously defined companions or familiar/student-created companions provide better learning opportunities. When students engage with an APA that is customizable to be similar to them will they feel more connected and able to identify with to it than with a general prescribed APA? Do companions that are more familiar and connected to students provide better learning opportunities?

Examining whether ELL students perceive the utility of and relate to a bilingual LC is also of interest. Based on the findings of this study, it is theorized that ELL students will be more engaged with their ILE and have a positive experience if they are able to identify and connect with a bilingual LC that has similar characteristics as themselves.

The notions of gender are now shifting due to activism and advocacy around human rights and the transgender movement. In the past, experiences have been shaped by a deeply entrenched gender binary, today, students live in a world where gender exists along a spectrum and gender diverse students are encouraged to live authentically. Though educational research has is very limited in regards to students who do not identify or exclusively identify with their sex assigned at birth. Further research is needed to look at variations of gender (transgender, non-gender, genderqueer/non-binary or gender-fluid) and math education and APA design. Of specific interest to the author are features that afford identity creation that take gender "out of the box" allowing for creation of non-conforming gender identities and roles. VLEs interactive and representation features should be designed to allow for "out of the box" gender identities and roles.

Based on the findings of this study, there is evidence to demonstrate that the MathSpring tutor and all ITSs with APAs should incorporate functionality for students to design the characteristics of their learning companions.

Conclusions

The purpose of this research was to evaluate the impact of the MathSpring (MS) animated pedagogical agent (APA) design and the student created learning companion (LC) designs, and to answer the questions: 'What aspects of the MS APA do Hispanic ELL students find helpful and in what ways?', 'Do the student designed LC avatars of Hispanic ELL students have similar characteristics and look like themselves?' and 'How do Hispanic ELL students describe their LC designs and why do they make their design choices?'. Two figured worlds (FWs) were found. First, the student and Jane, the MS APA, interaction and social engagement between the student and Jane, the MS APA, created a FW of learning in which Jane's encouraging and scaffolding features built learner confidence and better performance. Second, when students created their own LC designs a FW is developed in which the student connects with their learning companion.

This research demonstrates that learning companion design in online tutoring systems is very important for building student-tutor rapport and is connected to engagement, performance and learning. Based on the findings of this study, there is evidence to demonstrate that the MathSpring tutor and all ITSs with APAs should incorporate functionality for students to design the characteristics of their learning companions. This mixed-methods research demonstrates the more the learner identifies and engages with the APA the more likely he or she is to be immersed in the ILE, and to have a favorable or satisfactory experience.

The results indicate that ELL students find the MathSpring LC more useful and helpful than do non-ELL students and the ELL students designed LCs that looked more like themselves than did the non-ELL students. It is relevant to note that there was a statistically significant difference for the ELL and non-ELL students and not the Hispanic and Caucasian students. Evidence shows that because of language acquisition, students who are learning English as a second language have a stronger need and desire to identify and connect with a similar learning companion than do the Hispanic students, whose first language is English. If this is true, perhaps the ELL students would identify with, connect with and be even more supported by a LC that is bilingual and offers problem hint text and audio in both English and Spanish.

The qualitative data backs-up the quantitative results that indicate that the stronger the relationship between the ELL student and their LC (identification with the avatar), the more likely the learner will engage with the ILE and have a positive experience. The qualitative information elaborates on and deepens the verification of what the quantitative data demonstrated, increasing the quality of understanding of the experience.

APPENDIX A

CERTIFICATE OF HUMAN SUBJECTS APPROVAL

University of Massachusetts Amherst
108 Research Administration Bldg.
70 Butterfield Terrace
Amherst, MA 01003-9242

Research Compliance
Human Research Protection Office (HRPO)
Telephone: (413) 545-3428
FAX: (413) 577-1728

Certification of Human Subjects Approval

Date: May 31, 2016

To: Beverly Woolf, Computer Science

Other Investigator:

From: Lynnette Leidy Sievert, Chair, UMASS IRB

Protocol Title:Impact of Adaptive Interventions on Student Affect, Performance, and Learning
Protocol ID: 2013-1680
Review Type:EXPEDITED - REVISION
Paragraph ID: 7
Approval Date: 05/31/2016
Expiration Date:05/30/2016
OGCA #:

This study has been reviewed and approved by the University of Massachusetts Amherst IRB, Federal Wide Assurance # 00003909. Approval is granted with the understanding that investigator(s) are responsible for:

Modifications - All changes to the study (e.g. protocol, recruitment materials, consent form, additional key personnel), must be submitted for approval in e-protocol before instituting the changes. New personnel must have completed CITI training.

Consent forms - A copy of the approved, validated, consent form (with the IRB stamp) must be used to consent each subject. Investigators must retain copies of signed consent documents for six (6) years after close of the grant, or three (3) years if unfunded.

Adverse Event Reporting - Adverse events occurring in the course of the protocol must be reported in e-protocol as soon as possible, but no later than five (5) working days.

Continuing Review - Studies that received Full Board or Expedited approval must be reviewed three weeks prior to expiration, or six weeks for Full Board. Renewal Reports are submitted through e-protocol.

Completion Reports - Notify the IRB when your study is complete by submitting a Final Report Form in e-protocol.

Consent form (when applicable) will be stamped and sent in a separate e-mail. Use only IRB approved copies of the consent forms, questionnaires, letters, advertisements etc. in your research.

Please contact the Human Research Protection Office if you have any further questions. Best wishes for a successful project.

APPENDIX B
PARENT CONSENT FORM

Dear Parent or Caretaker,

We invite your son or daughter to participate in a project to study how people solve mathematics problems on a computer. This project will take place during the summer camp Eureka! as a part of normal camp activity. Your child will be invited to use a computerized tutor used by over 3,000 students and funded by the National Science Foundation and US Department of Education.

We will ask your child to answer some survey questions about their interest in mathematics, then ask them to work with the computer tutor, and then again ask them to answer survey questions. Researchers may walk around the room and note student emotions (e.g., interested, bored, frustrated). We will also record audio and video digital files of your child working. Your child's involvement will be 1.5 hours/day for up to 3 days. Only researchers will have access to this anonymous data and the link to any specific student will be locked away in a faculty office. We use an anonymous codename for each child and then only record numbers averaged over all students. The results of data and video may be distributed at research meetings, however your child's name will never be used and any facial features will be blocked out. The researchers will keep all study records in a locked file cabinet maintained in a separate and secure location. None of your child's data or answers will be linked to them personally. The master key and audiotapes will be destroyed 6 years after the close of the study.

If you permit your child to participate, we welcome you and your child. However, we fully understand if you decide not to participate. There are no known risks to your child's privacy if you decide to let them participate. There is no immediate risk to students themselves. A student can cease participation at any time. There will be no long-range risks. If you have any questions concerning your rights as a research subject, you may contact the UMass Human Research Protection Office (HRPO) at (413) 545-3428 or write humansubjects@ora.umass.edu. We are happy to share our results with you if you are interested. To get a copy of these results or have any questions call us at 545-1309 or write to ckchelp@cs.umass.edu.

Sincerely,

Ivon Arroyo, Ed.D., and Beverly Woolf, Ph.D.
Email: <ivon@cs.umass.edu> <bev@cs.umass.edu>

Please check if you consider use of this program appropriate and sign at the bottom.

____ Yes, I authorize my child to participate in this research, fill out surveys, be observed by researchers and be video-taped and use the tutoring software.

Child's Name

____

Name

Parent Signature

____

Name Date

APPENDIX C
STUDENT ASSENT FORM

Dear Student,

We invite you to use software during Camp Eureka! that might help you solve mathematics problems. If you agree to this, we will ask you to answer some questions about your interest in mathematics, then to work with software and then again to fill out a survey. Sometimes a person might walk around the classroom and write down some things about you. We will record audio and video digital files of you working with the software. The researchers will keep all study records in a locked file cabinet maintained in a separate and secure location. We are sending a note to your parents/caretakers asking them to OK your participation, so they know that we ask you to use this software. The results of data and video may be distributed at research meetings, however your name will never be used and any facial features will be blocked out Your name will not be written anywhere on the records and we will make sure that answers you provide here cannot be linked to you personally.

If you don't want to participate, you don't have to and you can stop at any time. You will do alternative camp activities if you do not participate. There will be no bad feelings if you don't want to do this. You can ask questions if you do not understand any part of the activity. If you agree to participate, we ask you to work with us during the workshop. There are no risks to you or to your privacy if you decide to join. To get a copy of these results call me at 413 545 1309. If you have any questions about this research or want to receive a copy of these results please call me at 413 545 1309 or write to me at ckchelp@cs.umass.edu

If you choose to participate, we welcome you. If you decide not to participate that is fine. If you have any questions about the web site, or about being in this workshop, please contact me at ckchelp@cs.umass.edu.
Researchers at UMass would like to use the data from this software as part of their research studies to see which techniques work best to support math learning. The Human Subjects Review Board at the University of Massachusetts Amherst has approved this project and can also answer any questions about privacy you might have. You can reach them at 545 3428.

If you choose to participate please press the agree button at the bottom of this screen.

Remember, by moving to the next screen you are agreeing to participate.
Sincerely.

Beverly Woolf
Research Professor,
Computer Science

Yes, I agree to participate in this Eureka study.   [ ]

APPENDIX D
CODER DISCUSSION TRANSCRIPT

Q1 – 'If you thought Jane was helpful, Why?' open coding discussion transcript - R1: "Should the 'Better understanding' and 'Better performance' categories be combined?" R2: "No, keep these separate. There's an interesting distinction the students are making here that might lead to some good discussion in your write-up" R3: "I would suggest separate these two concepts." R4: "Personally, I think there's a case to combine the two descriptors. Personally, I see better understanding and better performance as two steps in the same process. Better understanding generally leads to better performance." R1: "I agree with you R4, they are two steps in the process. I think for this data I think it is interesting to tease out the two different steps."

R1: "Do you think that the 'Engaging' and 'Connection' categories should be combined?" R2: "Yes, you could collapse these codes into one." R3: "Maybe "fun, engaging, etc." could be merged into "general positive learning process" if students do not make any specific comments." R4: "I'm more inclined to say separate connection & engaging. When reading the comments, many students felt engaged with the LC through audio and prompts. But it seemed like almost no student felt a connection until they were allowed to create a LC. Many students reported making the character look like themselves and that created a far greater level of engagement."

R3: "I really like the connection category, I really like this kind of analysis of language use, i.e. Pronouns (she/he/me) in this case." R1: "Notes about this category, she is an extension of me. We join forces for a common purpose to learn math, we play together, we play a game together to learn math, we learn, she is an extension of me. I have Jane, I am not alone." R3: "The feeling category is also a nicely summarized category, perhaps, also on a language use level, to some extent, as it deals with the use of the word "feeling". Maybe after reading some literatures or research a little bit further, we could come up with a better word to generalize this category."

R1: "What do you think about the 'Not helpful' and 'Indifferent' categories, should they be combined?" R2: "No, keep "not helpful" and "indifferent" distinct (although, to me, in these examples you might be able to combine "generally helpful" and "indifferent")" R3: "I would suggest keep them separate, because "not helpful" is different from "indifferent". Yet I have the same feeling that the examples provided are not quite typical, especially the two sentences for "indifferent"." R4: "Keeping "not help" and "indifferent" separated would be better. It seems like if a student described the LC as "not helpful" that thought occurred to them at some point in the program. But when students report being "indifferent" it feels like those students may not have been engaged 100% at the start."

Q2-'Describe your Learning Companion.' open coding discussion transcript - R2:" Some of the examples listed in the "creative/imaginative" category (specifically the anime ones) seem like they would fit here based on the definition of this category as including a favorite character." R3: "I agree with R2's idea. Give the lines another look. It looks like a movie character could go with "familiarity" Also, I may suggest having uniformity regarding the use of speech in "code scheme. I would suggest use either verb or noun phrases, or a complete sentence maybe if appropriate in some cases, but stick to either one throughout the coding system."

R1:" Fun, easy, good, helpful, cool - Is this all personality?" R2: "To me, the difference between personality and evaluation is that the "personality" code reflects an attribute of the character while the "evaluation" code reflects the student's experience interacting with the LC and program. R5:" I agree with R2 here." R3:"I agree with R2's idea. These are two tricky concepts. Yet, you may need to give each line a second look to make sure they are under a more appropriate category. On a side not, as you proceed, there could be codes on multiple levels. Like, for instance, descriptions of physical characteristics (hair, clothes, skin), gender, race, personality, etc. Then there could be evaluation (how students think of the character). Also, whether student self-replicate them for the learning companion, or have someone as a model (either a friend, a family member, or favorite movie character, etc.), or create just a completely new character could be another aspect in coding. "

Q3– 'Why did you design your Learning Companion the way you did?' open coding discussion transcript – R1:" Attractive, Cool and Smart, hmmm... should Attractive and Cool be combined or is there another over-arching way to describe these 3? or just leave as is?" R2: "Leave as is". R3: "Good points. It is kind of vague here, due to students' use of language to describe their learning companion. It seems reasonable to combine them by having another over-arching word." R4: "Those are really subjective adjectives. I like the idea of trying to find an overarching word that puts the shared feelings under the same umbrella."

R1: "There are not a lot of utterances that fall into the gender category, should I remove gender?" R2: "You could collapse it into "diversity" in cases where the student talks about their intention to defy traditional binary genders." R3: "Also terrific points. I would agree with Kathryn. If students do have more specific comments regarding their idea towards "diversity", it helps you to make some classifications, and gender could be one of the subcategories."

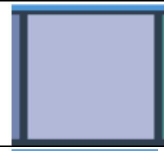
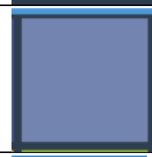
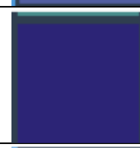
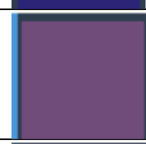
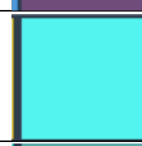
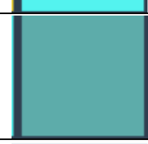
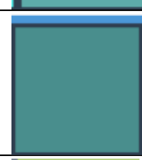
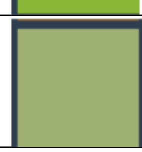
R1: "Should Favorite character and Familiar categories be collapsed into Familiar?" R2: "No. If anything, you could collapse "familiar" into "self-replication" because in some way, 'looks like a family member' is 'looks like me'. Whereas with enough data you might be able to tease out whether students prefer someone who looks like them vs. someone who they identify with in the popular culture (i.e., a celebrity or character)". R3: "I think having multiple layers of codes might help, though it needs more time to decide on how to categorize in a more reasonable way.

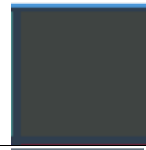
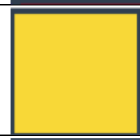
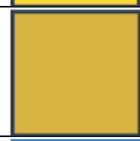
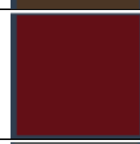
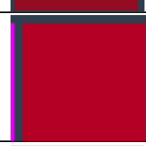
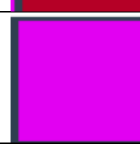
It may also have to do with the research question, the major goal of analyzing character (the learning companion), and what previous research and literature tell you." R4: "I think it's important to keep those codes separate. Familiar would cover the students who made LC look like themselves. Students that developed a LC after a favorite character likely have a deeper connection that's rooted in something more."

R1" Should the creative/imagination be called just 'Imagination' instead?" R2: "Either seems fine, or you could go with the same "creative/imaginative" code you have down for Q2." R3: "Yes, imagination, creation, they both work." R4: "It seems to be one in the same for this exercise. ".

APPENDIX E
MY BLUE ROBOT - EYE IRIS COLOR OPTIONS

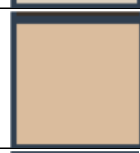
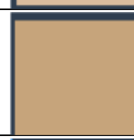
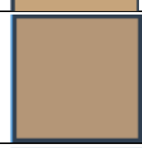
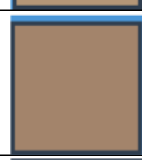
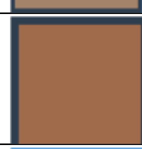
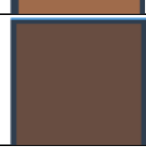
Table X: Eye Iris Color Options

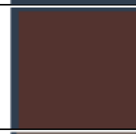
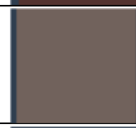
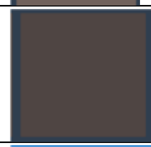
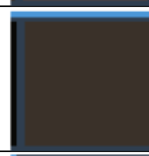
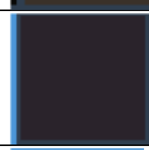
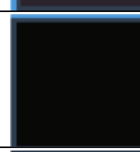
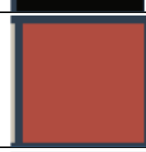
Eye Iris Color	Description	Organized by color; sorted from light to dark
1	Lightest blue	
2	Light blue	
3	Medium blue	
4	Dark blue	
5	Purple	
6	Light teal	
7	Medium teal	
8	Dark teal	
9	Green	
10	Light olive green	

11	Medium olive green	
12	Dark olive green/brown	
13	Yellow	
14	Yellow/brown or light brown	
15	Medium brown	
16	Dark brown	
17	Dark red/brown	
18	Medium red	
19	Light red	
20	Fuchsia pink	
21	Multicolor	

APPENDIX F
MY BLUE ROBOT - HAIR COLOR OPTIONS

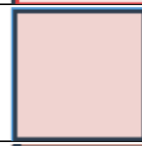
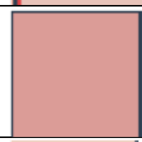
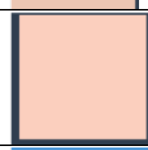
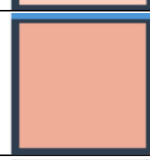
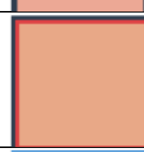
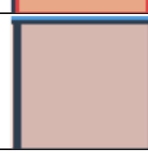
Table X: Hair Color Options

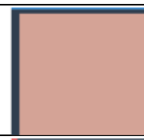
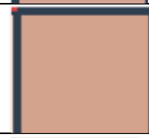
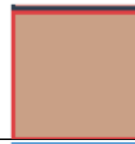
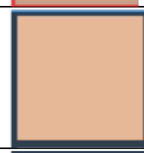
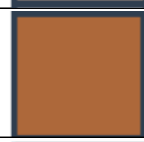
Hair Color	Description	Organized by color; sorted from light to dark
1	Light yellow	
2	Light pink	
3	Light taupe	
4	Light tan	
5	Medium tan	
6	Light golden brown	
7	Medium golden brown	
8	Light brown	
9	Dark golden brown	
10	Light red/brown	

11	Medium red/brown	
12	Dark red/brown	
13	Light grey/brown	
14	Medium grey/brown	
15	Dark grey/brown	
16	Medium black/brown	
17	Dark black/brown	
18	Black	
19	Medium red	
20	Dark red	

APPENDIX G
MY BLUE ROBOT - SKIN COLOR OPTIONS

Table X: Skin Color Options

Skin Color	Description	Organized by color; sorted from light to dark
1	Pale pink	
2	Light pink	
3	Medium pink	
4	Dark pink	
5	Pale peach	
6	Light peach	
7	Peach	
8	Medium peach	
9	Dark peach	
10	Taupe	

11	Dark taupe	
12	Light tan	
13	Olive tan	
14	Beige	
15	Golden brown	
16	Light brown	
17	Brown	
18	Chestnut brown	
19	Chocolate brown	
20	Dark brown	

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