Board 106: Did Math Make Me Move? The Design and Initial Evaluation of a Culturally Appropriate Gestural Educational Technology (Research)

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Abstract

Students nationwide are continuing to struggle in the area of Algebra, which is necessary to perform and enter science, technology, engineering and math (STEM) related fields. African-Americans, in particular, are underperforming in Algebra, and many other levels of math. Makin' Math Move is a gesture based math educational technology. It was derived from the desire to offer a technological solution for African American students to increase their motivation and academic performance in areas needed for success in Algebra level classes. Makin' Math Move works by supplying users with math problems and allowing them to solve them using gestures. For each of the standard math operations (add, subtract, multiply and divide), a gesture was trained and mapped to the intended operation. Students select one operand, perform a gestural operation and select an additional operand before supplying the system with their numerical input.

This paper will focus on the system design of Makin' Math Move and the initial usability study with 6th and 7th grade African American students. In order to build this system, several of the design considerations were influenced by 6th and 7th grade African American students. This initial usability study measured the gestural accuracy, overall usability and favorability, as well as the perceived cultural relevance of the system. Data suggested that further training and a second usability study, with the updated system, was required to have the gesture recognition at optimal performance; however, students were excited and liked the system in its current state.

Introduction

Society is becoming increasingly technologically advanced and the demand for more scientists, technologists, engineers and mathematicians is continually on the rise. In order to excel and pursue STEM career routes, Algebra has been a key requirement to gain access to such fields and related courses. Due to its importance, 32 states have made it a requirement for high school graduation[1]; the remaining states define the amount of math credits required to graduate, but do not specify which courses must be taken. Despite its importance and requirement by most states, students are not excelling in this area. While there is no national standard or standardized test to measure Algebra competency, most states offer their own end of course assessments. Additionally, there are national assessments and reports that gauge some level of algebraic performance of students in the 8th and 12th grades, which often occurs before many have taken the course and then after Algebra I and additional math courses have been taken. The National Assessment of Educational Progress (NAEP) is one such evaluation. Approximately 30% of the 8th grade test covers Algebra topics, while 35% of the 12th grade test encompasses the topic[2]. Although not tailored toward Algebra specifically, on average, the majority of students are not at the proficiency level for either grade level; 33% of 8th graders and 25% of 12th graders were at or above the level[3].

Research suggests that this is due to a weakened arithmetic foundation needed before the transition to algebraic thinking[4]. African American students are performing at an even less proficiency across all levels of math. African American students achieved the lowest proficiency scores amongst all racial groups, at all tested levels, on the 2015 NAEP assessment. Their proficiency percentages of 19%, 13% and 7% in the fourth, eighth and twelfth grades, respectively, were at least 50% lower than their White counterparts at each level. There have been a variety of factors associated with this gap in academic performance; one being the different and disjointed cultures African Americans experience in their home life and in their Eurocentric-styled academic life[5,6,7]. This disconnect, coupled with the poor math performance, was the motivation behind the design and development of a culturally relevant, full body gestural educational technology, entitled Makin' Math Move. Research shows that culturally relevant material is impactful on minority students and also that movement, when coupled with learning, has cognitive benefits. Makin' Math Move focuses on improving the pre-Algebraic foundation to ensure Algebra I success and also aims to improve student motivation in the mathematics classroom. This interdisciplinary work combines various research areas including culturally relevant pedagogy, essential algebraic content, natural user interfaces and gamification.

In this paper, literature related to the two biggest components of the development of this system, culturally relevant pedagogy and gestural based learning, will be discussed in detail. Next, the system design, architecture and implementation, will be explained thoroughly. The second half of the paper will explore the usability study and results. It will conclude in a discussion and their implications on the next phase of research.

Related Work

Culturally Relevant Pedagogy and Learning Technologies

For the last 30+ years, there have been various educational attempts to bridge the aforementioned disconnect between minority students' conflicting academic and home cultures[8]. Researchers have developed several pedagogies, which often overlap, to address the issues for various minority students, including those of Native American and Native Hawaiian cultures[9,10]. These terms include "culturally appropriate", "culturally congruent", "culturally compatible", and "culturally responsive"[9,10,11,12]. Each of these ideologies utilize cultural frames of references and aspects specific to that culture, such as language, and include them into traditional American curriculum. A widely referenced ideology that aligns with the aforementioned pedagogies is culturally relevant pedagogy, which was popularized by Dr. Gloria Ladson-Billings. Along with teaching ”through their own filters”, which also includes previous experiences and learning preferences, this practice also asserts that students must succeed academically, gain a critical consciousness and also challenge the social status quo[13?]. Along with Native American and Hawaiian student success, these pedagogies have found success with the African American student population via the use of sports, poetry and the inclusion of familiar community members who participated in culture-related classroom lessons[13,14,15]. Outside of the more common cultural frames of references, such as sports, A. Wade Boykin defined nine interrelated dimensions specific to the African American culture[16]. These dimensions include: spirituality, orality, harmony, expressive individualism, affect, social time perspective, verve, communalism, and movement. For Makin' Math Move, two of these dimensions, verve and movement, were incorporated into the design. Verve, which relates to the tendency to prefer lively stimulation, was incorporated via the visual and auditory design of the system. Movement was utilized when determining the input modality, which is a full gesture interface.

There has been some research that has resulted in the development of culturally relevant learning technologies focused on math and literacy skills for African American students in grades K-12. The African-American Distributed Multiple Learning Styles System (AADMLSS) City Stroll is a 3D environment with an urban neighborhood setting. AADMLSS uses cultural references of rap and hip hop music, along with an African American pedagogical agent as it seeks to help students practice various Algebra lessons[17]. AADMLSS was evaluated for usability with both junior and senior high school minority students; 96% of these students were African American. Although it wasn't tested for learning gains, overall, students enjoyed the technology and would like to have it integrated into their school curriculum. Culturally Situated Design Tools (CSDTs) also integrate cultural aspects into their applications which cover various educational topics[18]. The Cornrow Curves CSDT uses the African American cultural braiding technique to allow students to practice geometric skills by having students to create their own braids or mimic images supplied by the application. Translational geometric skills such as rotation, reflection and scaling are required to master intricate designs when creating cornrows. Ron Eglash's team of researchers have crafted over 15 CSDTs that are tailored to multiple cultures including African American, African, Native American and Latino. All of the CSDTs have not been evaluated for effectiveness, however the evaluation of the Virtual BeadLoom (Native American) CSDT did suggest that it could improve student performance in the area of coordinate planes when coupled with traditional learning techniques[19].

Two systems, *Rappin' Reader* and *Say Say Oh Playmate* were created by Nichole Pinkard in an effort to create motivating and culturally responsive literary environments[20]. In *Rappin' Reader*, the student acts as a writer for their favorite musical artist and is given several activities, such as unscrambling a song's lyrics, that work to improve the student's reading ability. The application also lets the student write their own song and create a music video for it. *Say Say Oh Playmate* uses clap routines, such as ”Miss Mary Mack”, to enhance students' sight word recognition and reading ability. The student joins a clap group and are able to practice by constructing current routines or can create their own. Both have been evaluated and *Rappin Reader* elicited performance gains for all participants, with a greater word gain for African American children over their Caucasian counterparts. Likewise, *Say Say Oh Playmate*, also saw performance gains by all students, with an average word gain of 9.7 words.

Kinesthetic Learning and Learning Technologies

The movement dimension, as defined by Boykin, is ”an emphasis on the interweaving of movement, rhythm, percussiveness, music and dance, which are taken as central to psychological health”[16]. One such aspect of said psychological health are cognitive abilities. Research has suggested that physical movement has had positive effects on academic performance which can be attributed to the enhancement of both the vestibular system and spatial awareness[21,22]. Kinesthetic learning has also have positive effects on cognitive functions associated with memory; by correlating educational material with body movement, research suggests it enhances the ability to retain and recall the information[23,24]. The theory of embodied cognition, which theorizes motor skills and higher level thinking processes are closely related, also heavily supports the notion of kinesthetic learning[25].

Kinesthetic learning activities can range in level of complexity (i.e. simple letter tracing) and technological enhancement (i.e. gestural educational interfaces). The plethora of devices featuring natural user interfaces (NUIs) allow for a wide array of possible implementations of kinesthetic learning in the classroom. NUIs are technologies designed to make the user experience and interaction seems as natural as possible; leading to a reduction in initial learning curve and often easier integration[26]. Natural user interfaces, specific to kinesthetic learning, encompass devices that allow for either single or multi-touch interaction (i.e. tablets to surface tabletops) or gestural based interaction (i.e Xbox Kinect). Due to our technologically enhanced society, the presence of such interfaces are common in classrooms. Tablets, in particular, have been seen to have positive effects on literacy performance in areas of handwriting and reading[27]. Less common are the inclusion of full body gestural interfaces in the educational space, excluding their use in physical education. *Jumpido* is one set of Kinect based games (commercially available at *www.jumpido.com*), that has employed full body gestural interaction in 60 different games for students in grades Kindergarten through six. The games offer opportunities for collaboration, competition and individual play with topics aligned with individual state and Common Core State Standards. Makin' Math Move also utilized the same range of gestural interaction to engage with a slightly older set of students.

System Design

Makin' Math Move is Unity-based system. It can be accessed via an executable application. Unity was selected as the development environment due to its support of the Kinect for Windows SDK. In addition to Unity and the Kinect, programming was completed in PHP and C.

User Interface

The interface design of Makin' Math Move has gone through relatively few changes. Figure 1 shows the initial mockup for the main screen of the system and Figure 2 shows the implemented interface used in the usability testing of the system.

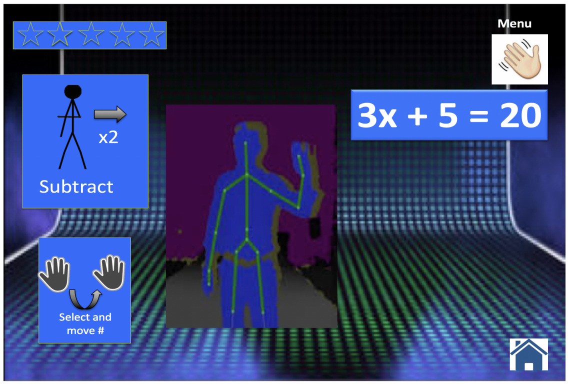

Figure 1: Mock-up of Problem Solving Screen

Figure 2: Implemented Problem Solving Screen

In order to select their settings, students must use the up and down arrows to navigate the page which can be seen in Figures 3 and 4. On this page, students get to select one option per each of the three categories: Background, Music and Avatars. Initially, there was only going to be one choice for the background design, but it was decided to add options to allow students to have a greater choice of customization. There are also multiple options for the music; all of the options are instrumental hip hop music clips. Students are allowed to preview the music by hovering the cursor, which is controlled by their right hand, over each option. There are six avatar options, three females and three males, for students to choose from. The avatars for each gender are identical in facial features, hair styling and clothing. The avatars differ in the range of skin color; there is a fairer-skinned, brown-skinned, and darker-skinned version of the male and female avatars.

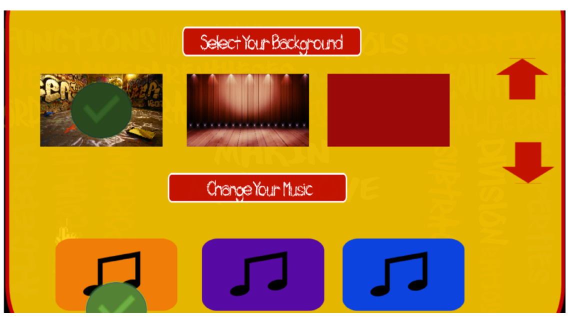

Figure 3: Background and Music Settings

Figure 4: Avatar Settings

The avatars were created using two applications owned by Adobe, Fuse and Mixamo. Fuse allowed for the creation and customization of each of the avatars. Here, avatars could be altered based on various categories including body type, skin color, hair styling, clothing and shoes. The software allows for personalization of even the smallest details such as crafting the faces to express different levels of excitement or anger. Once the model was created in Fuse, it was uploaded to Mixamo. Mixamo added the necessary rigging mechanisms.

Modes

The system offers three different modes and a demo/tutorial for the user to interact with. The demo/tutorial is a short video that walks through how to solve problems in the system, as well as navigational functionality. The first mode, the ”Dress Rehearsal” features an area where users are allowed to solely test the accuracy of their gestures against the system’s recognition database. Users will select from the given functions (add, subtract, multiply, divide, home, help, pause or next) to choose which gesture they want to practice. An image or animation, depicting the gesture, will be displayed in the upper left hand corner of the screen. The user (and their avatar) will then perform the gesture. A text box will appear if the gesture was performed correctly as well as a percentage representative of the system’s confidence in recognizing the performed gesture. The user can practice any and all of the gestures as many times as they desire within this section.

The other two sections or modes are where they actual mathematical practice will take place. Essentially, both areas of practice will feature the same content and design; the only difference is one will be more of a guided practice and offer hints, while the other will be less scaffolded. The Guided Practice area allows students to practice various types of equations based on the content selected for this system; the content employed in Makin’ Math Move will be discussed in greater detail in the following subsection. Students will be shown a problem and instruction for the problem (e.g. ”Solve For x” or ”Complete the problem using Order of Operations”). Students will also be shown an image or animation corresponding to the first gesture/mathematical operation necessary to solve the problem. Students will then begin the problem solving process by selecting their first operand (which is either a single number or variable with or without a coefficient), which will become highlighted (Fig. 5). Next, they will perform the gesture that corresponds to the math operation that is shown. The screen will update to show that the operation was performed. Figure 5 shows that the operation desired was subtraction and Figure 6 shows the immediate result after performing the subtraction gesture. Notice the inclusion of the subtraction symbol on the screen. Then, they will select the second operand for this step in the equation; Figure 7 shows the result after this selection. If at any point in this process, the selection is incorrect (wrong operand or operator), the system will display a message bubble with a hint that informs them which action was incorrect and suggests how they can arrive at the right selection. The problem will reset and the student can begin again; if it is a multi-step equation, it will only reset to the beginning of that step.

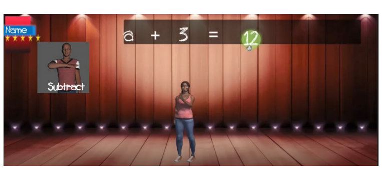

Figure 5: Selecting First Operand

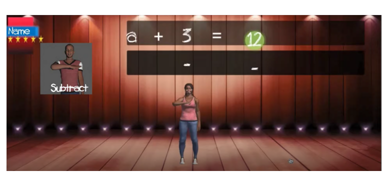

Figure 6: Performing the Correct Gesture

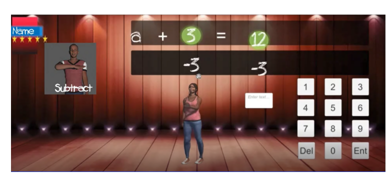

Figure 7: Completing the Problem

Once the correct operands and operator have been selected, a virtual numerical key pad will be displayed and the student will be able to input their answer. The system will inform the student if the answer for this step is correct or not. If the answer is correct and for a multi-step equation, they will repeat the process until they successfully reach the final answer. If the answer is correct and the problem has been solved in its entirety, the student can move on to another problem by performing the 'Next' gesture or utilizing the on-screen button. If the answer is incorrect, the system will alert the student and erase the text box so that they can try again.

System Architecture and Implementation

Makin' Math Move is comprised of five main components that work together to gather and display information from and to the student user.

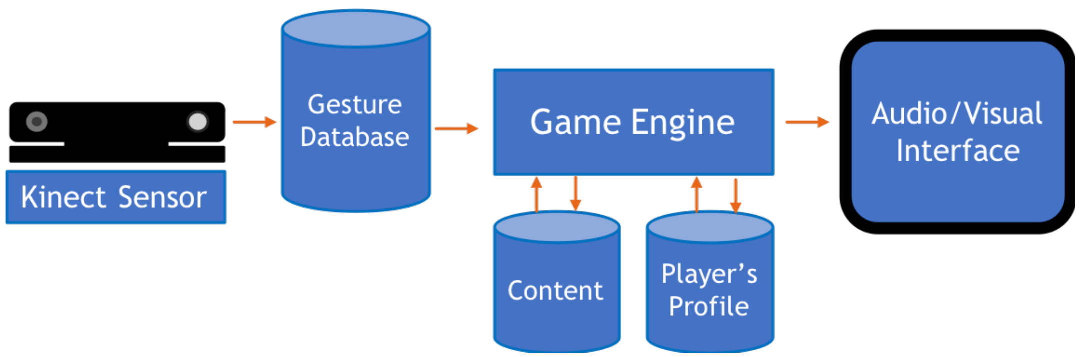

Figure 8: System Architecture of Makin' Math Move

Kinect Sensor

The first component is the Microsoft's Kinect for Windows sensor. The Kinect for Windows sensor is a standalone version of the sensor utilized within the Xbox gaming systems. The sensor and its software development kit (SDK) allow for skeletal tracking of up to 25 joints for 6 distinct people, voice recognition capabilities through its embedded microphone, shared use of a single sensor by multiple applications simultaneously and many other features. The sensor's SDK was essential in the developing of the next component, the gesture recognition database.

Gesture Recognition Database

The gesture recognition database was created with the use of two applications provided by the SDK, Kinect Studio and Visual Gesture Builder (VGB), which allow users to manage and work with gestures to be used in Kinect-enabled applications. The Kinect Studio allows users to record and save clips of their gestures, view data collected by the sensor in different views (2D, 3D, infrared, or color), and playback recorded data. The data recorded in Kinect Studio is then utilized in the Visual Gesture Builder. The VGB transforms this information into data that is usable by gestural based applications. The developer tags the beginning and ending of clips using gesture detection techniques, AdaBoostTrigger (discrete) and RFRProgress (continuous) , to train a specific gesture. Training continuous gestures also requires the tagging of progress stages between any discrete gestures that make up the overall continuous gesture. For example, if training a singular sit and stand gesture, the developer must tag the period for which they are sitting (discrete), the moment they begin standing (progress), the period for which they are standing (discrete), and the moment they begin sitting (progress). The amount of training (number of clips tagged) required varies based on the complexity of the gesture. The trained gestures are then compiled and built into the gesture recognition database. The gesture database was then able to be imported as an asset into the game engine component.

Unity Game Engine

As mentioned previously, the system was developed using the Unity game engine. This component is the center of the entire architecture and works with the various other components to execute the problem solving functionality by receiving and sharing information with the three databases (gesture, content and player's profile) and displaying information to the user.

Player's Profile Database

The player's profile database consists of not only the student's settings customization, but also tracks their progress. It will keep a record of their time spent on each question, hints used, as well as the status for each problem (correct or incorrect).

Content Database

The content database houses all of the problems utilized within the system and communicates with both the game engine in order to relay what information is to be used as well as the player's profile database to update the status of the students' success.

Presentation Module

The final component, the presentation module, refers to the displaying of the technology to students and is inclusive of all visual and audio components.

Initial Evaluation

Purpose

The objective of any usability study is to ensure that the system being evaluated is functioning adequately to accomplish its intended goal. The purpose of this study was threefold and tested not only the visual interface and gestural recognition capabilities of Makin' Math Move, but also an underlying intentional design choice. The usability study sought to address the following questions: *Is Makin' Math Move usable, in terms of gesture accuracy and overall system usability?* and *Is Makin' Math Move deemed culturally relevant by African American students?*.

Measures

In order to quantify each of the three testing factors, three different measures were utilized. A standard System Usability Survey (SUS) was administered following each student's usability session. The SUS consisted of ten statements accompanied by a 5 point Likert Scale; responses ranged from 'Strongly Agree' to 'Strongly Disagree'. Along with SUS, the student completed a survey created by the lead researcher that asked questions regarding their demographics, experience with the Kinect and gathered specific feedback about the system. The second part of the survey consisted of questions used to assist in determining the cultural relevance of the system. In order to determine gestural accuracy, the researcher indicated in their notes during the observation if each student was able to successfully perform the gesture, as recognized by the system. The time was also recorded via the system to indicate task completion; time was stopped when the student either successfully triggered the gesture and completed the task or when they failed to complete the task and decided to move on to the next task.

Participants

Participants for this usability study were recruited from a STEM-focused summer camp at a predominantly African American area charter school. The camp was for students who had just departed from grades Kindergarten through sixth grade in the Spring. The population targeted for this study were African American students who had just completed the sixth or seventh grade. There were approximately 20-25 students who met these requirements, but only 9 students returned parental consent forms and assented to the study. The results discussed in this paper will only feature the sessions for eight of the nine students; the first session experienced multiple technical delays, which resulted in the student not being able to complete the study. Of the eight participants, six identified as Black/African American, one identified as being multi-racial (which did not include African American) and one identified as being Haitian-American. Six of the students were female (two males) and five had immediately completed seventh grade, while the other three had finished sixth grade. In regards to previous Kinect experience, only two had interacted with the device before.

Procedure

Each study session began with each student reading and completing the assent form. Next, the purpose of the study was reiterated to the participant (it was briefly explained on the assent document), as well as a general overview of how the study would proceed. There were 13 tasks to be completed in the study. Students were informed that they could spend as much time as they wished on each task and could also choose to skip ahead to the next task if they felt that they could not complete it.

- Tasks 1-3 consisted of steps needed to get students to the practice page.
    1. Settings: ”Select your background, music and avatar and go to the next screen.”
    2. Mode: ”Navigate to the Guided Practice areas.”
    3. Topic: ”Navigate to the Usability Study topic.”
- Tasks 4-7 asked the students to solve basic, single digit equations for each of the four basic math operations (addition, subtraction, multiplication and division). The interface displayed the corresponding gesture to perform for each operation.
- Tasks 8-11 asked the students to perform gestures for the navigational functions (home, help, pause and next problem). The image for each of these gestures was also displayed on screen. It is important to note that for the *Help* function, students were presented with images of three different gestures (Punch, Kick, Milly Rock, which is an African American cultural dance move) and asked to select which one they wanted to associate with this specific function. This is due to the fact that these three gestures received the same agreement frequency in a previous gesture elicitation study. The results from this study will be used in determining which of the three gestures will be utilized in the final implementation of this system.
- Tasks 12 and 13 required students to solve two more complex math problems. The first was a one-step Algebra problem (A + 6 = 9) and students were asked to solve for the letter A. The second problem was an Order of Operations styled problem which consisted of three operations.

Once all 13 tasks were attempted, participants completed one large survey, which consisted of the demographic survey, SUS, cultural relevance measurement questions, and other questions related to their participation in the study. After the conclusion of the survey, participants engaged in a short interview with the primary researcher.

Results

Task Completion and Gestural Accuracy

Of the 13 tasks, only 5 were able to be successfully completed by all students and these included tasks 1 and 2 (selecting settings and navigating to the guided practice page) and three of the four navigational gestures (home, help, and pause). The more complex math problems (Tasks 12 and 13) were the hardest to complete; only one student as able to get both tasks completely correct. Students went on to report in the survey that several of the gestures were hard to perform with the most frequent response being for *Add* (31.25%) and *Next* (25%). The tables below present the means of the number of tasks completed by each grouping (Gender, Grade and Kinect Use).

T-tests were conducted for each grouping assuming equal variance; none of the differences proved to be statistically significant. A table displaying the success rate of each task is also found at the end of this section, along with the average task completion time.

Grade	Number(N)	Task Completion	Standard Deviation (SD)
6	3	9.33	1.53
7	5	8.4	1.67

Table 1: Average Task Completion by Grade

Gender	Number(N)	Task Completion	Standard Deviation (SD)
Male	2	9.5	2.12
Female	6	8.5	1.52

Table 2: Average Task Completion by Gender

Previous Kinect Use?	Number(N)	Task Completion	Standard Deviation (SD)
Yes	2	10.5	0.71
No	6	8.17	1.33

Table 3: Average Task Completion by Kinect Use

Task	Tasks Completed Successfully By Participants	Average Time Spent on Task (s)
1	8	80.74
2	8	12.35
3	4	41.56
4	4	91.40
5	5	45.83
6	6	65.54
7	7	33.17
8	8	6.76
9	8	17.21
10	8	15.28
11	2	54.81
12	1	75.70
13	1	69.01

Table 4: Task Completion

Usability

After calculating the SUS scores for each of the eight participants, the scores were averaged with a result of 52.5. Research suggests that a score above 68 would be considered average. Based on a widely cited article, which adds an adjective rating to the SUS scale, a score of 52.5 would fall between the range of ”Ok” and ”Good”[28]. The tables below present the average SUS scores for students by gender, grade and previous Kinect use. To determine if there were significant differences between the means from each group, t-tests were conducted. Due to the small sample size during this evaluation and results from F tests, the tests were ran assuming unequal variances. None of the differences proved to be statistically significant.

Grade	Number(N)	SUS Mean	Standard Deviation (SD)
6	3	47.5	2.5
7	5	56	19.89

Table 5: Average SUS Score by Grade

Gender	Number(N)	SUS Mean	Standard Deviation (SD)
Male	2	47.50	3.54
Female	6	54.58	18.13

Table 6: Average SUS Score by Gender

Previous Kinect Use?	Number(N)	SUS Mean	Standard Deviation (SD)
Yes	2	49.58	15.28
No	6	49.58	15.28

Table 7: Average SUS Score by Kinect Use

Cultural Relevance

A portion of the cultural relevance measure was adapted from two measures, the Child Activity Questionnaire and Questionnaire of Stimuli Preference, utilized by A. Wade Boykin and colleagues as a means of measuring movement and verve in third and fifth graders in a study analyzing some of interrelated dimensions mentioned in the Background section[29]. The Child Activity Questionnaire evaluates students' awareness of their expressions of movement using three subscales with items measured using a 5-point Likert scale ranging from 1 (Almost never) to 5 (Almost always)[30]. Of the three subscales, only the adapted questions from the subscale related to *Movement/Music Mosaic* was administered to students. The descriptive statistical information from this subscale can be seen in Table 8.

The Questionnaire of Stimuli Preference evaluates students' proclivity for varying stimulating school activities. It also features three subscales for each of the three verve dimensions (Stimulus Intensity, Stimulus Variability and Stimulus Density) and scores items from 1 to 3, with 1

Min	Max	Mean	Std. Dev.	Variance
1	5	3.0	1.285	1.652

Table 8: Descriptive Statistics for Movement/Music Mosaic Subscale

signifying the lowest stimulus response[31]. In the context of this system, stimulus intensity refers to liveliness of the interface and presented content. The variability refers to the amount of variety in activities and the density refers to the number of stimulating elements. For the survey administered to students, two questions from each subscale was adapted to be context specific to the system and usability study. The descriptive statistical information from this measure can be seen in Table 9.

Stimulus Type	Min	Max	Midpoint	Mean	Std. Dev.	Variance
Intensity	2	3	2	2.75	0.45	0.2
Variability	1	3	2	2	0.89	0.8
Density	1	3	2	1.813	0.54	0.3

Table 9: Descriptive Statistics for the Questionnaire of Stimuli Preference

Additional Results from Survey, Interview and Observations

The survey asked students which gesture did they prefer for the *Help* function and 6 (75%) of the participants reported the punch or ”Whip” motion, although only 3 participants actually performed that gesture during the study. Half of the participants reported that they were not fully clear what each gestural image was trying to portray. Despite low SUS scores, only 2 students reported that they were not interested in using the system. A large percentage (87.5%) of the students enjoyed the music options provided.

Discussion and Future Work

Gestural Accuracy and Task Completion

The low recognition rate/task completion of the core mathematical operational tasks suggested that the system was not trained enough to elicit proper results. For some students, the inability to gain gesture recognition in the basic four math functions prevented some of them from being able to succeed in the more complex math tasks (tasks 12 and 13). For the majority of both of those two tasks, students a) could not get the system to recognize the operational gesture and/or or b) just did not know how to solve the problem (with or without the system). Of the 7 students who were unable to complete both tasks 12 and 13, two knew and vocally expressed how to solve the Algebra problem (task 12), but experienced gestural recognition issues; one student knew and vocally expressed how to complete the order of operations problem, yet experienced similar technical issues. As a result of this observation, the usability study ended prematurely with the 8 participants in order to perform additional training of each of the gestures and conduct another usability evaluation with 20 students. Videos collected by the researcher were reviewed and considerations were taken into account on how to retrain the gestures based on how students performed them in the videos. The *Multiply* gesture, for example, required the crossing of arms in the formation of an 'X' in front of the chest. It was noticed that students were often holding their hands in fists and also resting their arms against their chest, as opposed to performing their gesture off of their body. It was important for the researcher to include these variations in gesture poses in the retraining to ensure that the system will recognize all the deviations and attribute it to that specific function.

Usability

It is believed that the low gestural recognition rate of the system could have negatively affected the students' perceptions of the system and perceived usability. The increased training has the potential to result in a more smoothly executed system and increase students' ease of use. It was also noticed that a few students had issues understanding some of the vocabulary used in the SUS scale and asked for, as well as received, clarification. In the next usability study, it will be stressed that they should feel free to ask any questions to make the survey more understandable. Currently, there's no adapted SUS for the targeted demographic of participants that would be more suitable for their comprehension.

Cultural Relevance

Based on the results from the *Movement/Music Mosaic* subscale, featured in Table 8, combined with results from additional survey and interview questions, this limited study suggests that students enjoyed the presence of music in the system and did not find it to affect their ability to execute the steps essential to the problem solving process. A majority of the students enjoyed the options presented in the system and some requested the option to have more of the same style of music to choose from; this may be implemented for the final evaluation. Based on the means on each of the three verve dimensions found in Table 9, it can be concluded that students felt that the system was above average with regards to stimulus intensity, average in terms of stimulus variability, and below average for stimulus density. There will be no change to the system in terms of this measure before the next full round of usability testing. Any changes, primarily just in the area that relates to stimulus density, will be made based on the results of the next evaluation. While this measurement is important, it does not have a strong effect on how the students will be able to complete the tasks.

Conclusion

Makin' Math Move is a culturally relevant, full body gestural educational technology designed and developed to provide supplemental pre-Algebraic practice for African American students.

This usability study sought to determine the overall usability of the system, the accuracy of the gestural recognition database and also the amount of perceived cultural relevance in the system. Due to limited participation at the recruitment camp, combined with noticeable observations in the students' ability to gain recognition by the system, it was decided to treat this study as an initial usability study. Data, such as video recordings, was used to alter the existing recognition database by studying students' movements and retraining gestures accordingly to cover the variations in posing. A secondary study will be executed with the desired sample size of 20 students with the retrained database. Despite the inability to successfully complete some of the tasks, students in the initial study were excited to participate and liked the idea of such a system to help with practicing math skills.

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